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Utility of Historical Catch Data in Setting Reference Points for the British Columbia Shrimp by Trawl Fishery

Utilité des données historiques sur les prises pour établir des points de référence pour la pêche de la crevette au chalut en Colombie-Britannique

D.T. Rutherford, L.L. Barton, G.E. Gillespie; J.A. Boutillier

Fisheries and Oceans Canada
Pacific Scientific Advice Review Committee
Pacific Biological Station, Nanaimo, BC V9T 6N7

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ABSTRACT

The current assessment and management framework utilizes fishery independent survey methods to index shrimp biomass in selected Shrimp Management Areas (SMA's). Annual catch limits in surveyed SMA's are set based on applying a harvest rate to the estimated biomass index. Annual catch limits in the non-surveyed SMA's are set through two different methods. For some SMA's biomass is indexed through extrapolation procedures using neighbouring survey sites. For all non-indexed sites arbitrary catch ceilings are set by fish managers.

Historical catch data from the shrimp trawl fishery is not a suitable proxy for abundance. Historical catch data have poor resolution to species or current management area and lack supporting information to track stock trends over the historical time period. Even in the hypothetical event that historical catch did track past abundance, the shrimp trawl fishery is undergoing profound changes including size and species specific targeting which would invalidate the use of historical catch records in reference point models.

RÉSUMÉ

Le cadre d'évaluation et de gestion actuel utilise des méthodes de relevé indépendantes de la pêche pour obtenir un indice de la biomasse des crevettes dans certaines zones de gestion des crevettes (ZGC). Les limites de prises annuelles dans les ZGC étudiées sont fondées sur l'application d'un taux de prise à l'indice de biomasse estimé. Les limites de prises annuelles dans les ZGC non étudiées sont établies à l'aide de deux méthodes différentes. Dans certaines de ces ZGC, l'indice de biomasse est établi par extrapolation de données sur l'abondance obtenues dans des sites de relevé avoisinants. Pour les sites où aucun indice de biomasse n'a été établi, des limites sont fixées de façon arbitraire par les gestionnaires des pêches.

Les données historiques sur les prises de la pêche de la crevette au chalut ne constituent pas un indicateur approprié de l'abondance de la crevette. Elles ne donnent pas beaucoup d'informations sur les prises par espèce ou par zone de gestion et ne permettent pas d'étudier l'évolution des stocks. Si ces données constituaient une bonne approximation de l'abondance passée, le fait que la pêche de la crevette au chalut fait présentement l'objet de profonds changements, notamment en ce qui a trait aux objectifs relatifs aux tailles et aux espèces, invaliderait l'utilisation de ces données dans les modèles de points de référence.

1.0 Introduction

The shrimp trawl fishery off the Pacific Coast catches 7 species of shrimp belonging to the family Pandalidae: northern (or spiny) pink *shrimp (Pandalus borealis eous*), smooth pink shrimp (*P. jordani*), sidestripe shrimp (*Pandalopsis dispar*), coonstripe (or dock) shrimp (*Pandalus danae*), humpback shrimp (*P. hypsinotus*), flexed pink shrimp (*P. goniurus*), and prawn (*P. platyceros*)(DFO 1999a). The fishery varies in complexity from single to multi-species harvest and products are delivered to a variety of markets including machine-peeled, hand-peeled, frozen-at-sea, fresh, and live (Convey *et al*. in prep). Demand for shrimp on the west coast started to develop in the late 1950's with the development of automated peeling machines (PCSCA 2003). Up to 1996 the commercial shrimp trawl fishery was generally open year-round, with no catch limitations and the majority of landings were a mix of pink shrimp (>90%) and sidestripe shrimp. Starting in 1995 effort increased sharply and the fleet moved into areas that were not historically fished resulting in unprecedented catches in many areas (Southey *et al*. 2002). Factors thought to be responsible for the dramatic increase in shrimp trawl effort include declining trends in other fisheries (in particular salmon and groundfish trawl) the high price offered for shrimp, and abundant shrimp stocks in those years (DFO 2001).

In response to the increase in effort, landings, and number of shrimp species targeted, significant changes in the management of the shrimp trawl fishery were implemented in 1997. These changes included an assessment program that was partially funded by industry. Shrimp Management Areas (SMA's) were developed and area catch ceilings were established. A hail and landing record program was established to monitor catch in-season. The assessment program was tailored after the West Coast Vancouver Island (WCVI) shrimp assessment program where swept-area trawl surveys are used to index shrimp biomass (Boutillier *et al*. 1999; Martell *et al*. 2000). Following some exploratory and experiment survey designs in 1997, swept-area trawl surveys were implemented in selected Shrimp Management Areas to index shrimp biomass annually and to monitor trends in abundance. The Stock Assessment Division was also investigating the applicability of using these "survey areas" to index shrimp biomass in neighbouring SMA's.

The shrimp survey assessment program has now been in place for 5 years but continuation of the program is uncertain due to a potential reduction of industry funding. Cold water pink shrimp prices have dropped dramatically and as a result fishers are finding it difficult to continue funding their share of the assessment and management component at previously established levels. Several options that include scaled back assessment and management programs to reduce cost have been proposed.

This working paper has been prepared in response to a request from Fishery Managers "to demonstrate the long term benefits of a science based assessment, rather than using historical average catches at periods of low levels of fishing" (Appendix 1).

In this report we focus on the utility of historical catch data to set biological reference points for managing the shrimp trawl fishery. We first discuss in general terms biological reference point models and the assumptions that need to be met when using historical catch data as an input parameter for reference point models. We then present information on historical shrimp catch by the shrimp trawl commercial fishery and highlight some of the information constraints. We briefly review the current assessment framework and provide stock dynamic information highlighting the large annual fluctuations in shrimp biomass. We then demonstrate the shortcomings and pitfalls of abandoning the assessment framework and using only historical catch data to ensure stock conservation of the shrimp stocks along the coast of British Columbia.

1.1 Biological Reference Points

Many researchers have directed their efforts on developing various models for the setting of biological reference points for stock management and conservation (Caddy and Mahon 1995, Gabriel and Mace 1999, FAO 1995, Zhang 1999). The choice of which model to use is predicated by the life history of the animal, and availability of catch, relative abundance, stock recruitment and age specific mortality, growth and maturity data. The cost and logistical constraints of collecting and determining these parameters more often than not results in only partial information being available. In recognition of these constraints fish stocks are often catagorized into data rich, data-moderate, or data poor situations. If data are insufficient to determine yield or stock per recruit or if estimates of F (fishing mortality) or B (biomass) cannot be obtained there are fewer options for defining meaningful reference points. In data poor situations managers or researchers often use proxies for the input parameters. Gabriel and Mace (1999) state that if there is absolutely no information available to estimate fishing mortality or biomass it may be reasonable to use historical average catch as a proxy for *MSY*. They do however qualify this by stating that one needs to select a period where there is no evidence of declining abundance. In addition if catch data is unreliable, covers only a short time period, is driven by management actions, or significant changes to fishing practices/effort have resulted, then it will not be useful as an index of abundance and therefore would be unusable as the sole parameter for setting meaningful reference points.

1.2 Overview of Catch Reporting and Monitoring

Catch reporting/monitoring for the Pacific Coast commercial fisheries began with the introduction of the province-wide multiple sales slip system in 1951. This reporting system required that information on type of fish, weight, gear, location, number of days fished and landed value be completed, on delivery of fish to a company or buyer. One copy of the multi-part sales slip was designated for use by the Department of Fisheries of Canada for development of fisheries statistics. The departmental copies of the information were summarized by a branch of the Markets and Economics Service and reported as an annual publication. This publication series represents the earliest comprehensive reports of catch and effort in the commercial shrimp trawl fishery. Shellfish species were presented as monthly landings by area. Shrimp species were

grouped as pinks, prawns, humps, coon stripe, giant red (sidestripe) and mixed. For the 1952 annual report, the shrimp species were further grouped and reported only as prawns or mixed. Gear was reported as trawl or trap. Locations were presented as North Coast (District 2) which included areas 1 through 11, South Coast (District 3) which included areas 12 through 27 and Fraser (District 1) which included areas 28 and 29. Annual publications of similar, general format were produced from 1951 up to 1995. Minor format changes were introduced over the years. A detailed forward was originally included in the annual publication, describing events and occurrences such as regulation changes, weather patterns and labour disputes, which may have affected the information contained in the report. The detailed nature of the forward was eliminated during the 1960's. Ownership of the publication has remained within what is now Fisheries and Oceans Canada. Responsibility for publication has been moved from Economics Branch to, most recently, Corporate Services Branch. Commencing in 1996 the format of the reports changed. Data were segregated by broad species groupings: salmon, herring, halibut and shellfish. Four separate reports were created for the shellfish group. Shellfish were now annually summarized by landed weight or by landed value, and resolved either by area by species (prawns and all other shrimp) or by species (prawns and all other shrimp), gear type and month.

More detailed reporting of commercial catch and effort information began in 1975 with a voluntary logbook program, with responsibility for this program residing within Science Branch of the Department. At this time, commercial shrimp trawl fleet activity occurred primarily off the west coast of Vancouver Island. The number of vessels reporting per year ranged from a low of 1 (1975, 1981) to a high of 18 (1977). Unlike the sales slip data where effort was reported as number of days fished, logbooks collected number of minutes towed. The logbook data also provided greater resolution of location, with opportunity to report start and end co-ordinates for individual tows, as well as discriminate between in-shore and off-shore statistical (Pacific Fishery Management) areas and sub-areas. The voluntary logbook program remained in place through 1986, at which time the program was expanded and instituted as a mandatory requirement.

Commencing in 1987, the mandatory shrimp trawl logbook program collected catch weight by species, effort as number of minutes towed, statistical area and sub-area, as well as corresponding place name information and broad class of gear as either beam or otter trawl. In subsequent years the nature of the data collected has continued to evolve. 1997 saw the introduction of tow by tow reporting of location by latitude and longitude. Greater emphasis was also placed on differentiating between species, although pink shrimp are still generally reported as a single group. Responsibility for the logbook program has remained within Science Branch, Stock Assessment Division. The requirement to complete and submit harvest logs was established through condition of licence; an ongoing issue has been compliance with the licence conditions within the specified timeframes.

A number of management initiatives were implemented in mid-1997 that generated additional catch monitoring and reporting data. A hail program and landing record program were developed and implemented by Fish Management Branch to monitor the commercial fishery activities relative to area quotas instituted at this time. Quotas were assigned to shrimp management areas (SMA's), defined as groupings of Pacific Fishery Management Areas (PFMA's) and sub-areas. The hail program collected information, in the form of a verbal notification, on gear type (beam or otter trawl), effort (measured as days fished), buyer, SMA fished, landed weight by species, port of offloading, and, more recently, refinements to effort to include total hours towed. The landing record was a 2-part report. Part 1 Catch Summary represented a written account of the information presented through the verbal hail. Part 2 Sales Record was developed as a replacement for the traditional multi-part sales slip, allowing for reporting of the data items previously reported on sales slips without industry having to use a third record keeping book.

2.0 Methods

2.1 Data Sources

2.1.1 Fishery Dependent Data

Catch and effort data from the shrimp trawl fishery were obtained from the SHTRAWL database maintained by the Shellfish Data Unit, Stock Assessment Division. This database contains the logbook information for this fishery commencing in 1987 when the mandatory logbook program was imposed. Catch prior to 1987 was obtained from a Shrimp trawl fishery update (Convey *et al*. in prep), which contain tables of catch data obtained from sales slips. The SHTRAWL database is continually updated, as logbook information becomes available. Information captured in the logbooks includes: time set (year/month/day/hour), tow duration (minutes), tow distance (nautical miles), start location (lat/long) in degrees and minutes, statistical area and sub area of tow, minimum and maximum tow depth, weight of retained shrimp catch by species, gear type, vessel and skipper information (Appendix 2).

Another component of fishery dependent data is obtained through a bycatch sampling program. This program utilizes on-board observers who collect catch and bycatch data. All catch is recorded as species specific weights and a sub sample of the commercially important shrimp species are retained and forwarded to the Pacific Biological Station for sex, size and subsequent age determination.

2.1.2 Fishery Independent Data

All estimates of shrimp biomass presented in this paper were obtained from swept area trawl surveys carried out by Fisheries and Oceans Canada, Stock Assessment Division. Data from these surveys are entered, verified and stored in the SHRIMPTR database maintained by the Shellfish Data Unit, Stock Assessment Division.

2.2 Fishery Independent Biomass Estimation Procedures

2.2.1 Direct Estimation Procedures

Industry supported fishery independent swept area shrimp trawl surveys have been carried out annually in 9 selected SMA's commencing in 1998. The SMA's surveyed are PRD, 12IN, 12OUT, GSTE, 16, 18, 19, FR, and 23IN (Fig. 1). In addition to these areas DFO StAD surveys 5 off-shore SMA's (21OFF, 23OFF, 124OFF, 125OFF, and QCSND). The surveys are synoptic in nature and follow a systematic design with trawl locations spaced throughout the shrimp grounds. To ensure locations of greatest commercial fishing effort were included in the survey we identified these areas through both logbooks and consultation with local fishers. The 50m and 200m contour lines on the Canadian Hydrographic charts were used to define the approximate upper and lower distribution of shrimp habitat in each of the survey areas. The shrimp grounds were masked and captured digitally and incorporated into a geographic information (GIS) system. Within each mask, a sampling grid was established which partitioned the mask area into blocks of 0.25 square nautical miles.

The index of shrimp biomass was estimated as follows: for each trawl tow a catch density for each shrimp species was calculated by dividing catch by area swept. This density was applied to the .25 nm^2 grid where the centre point of a tow occurred. The blank grid cells were filled in with interpolated values and the biomass indices were calculated by summing the values in each grid within the larger masked boundaries of each survey area. The bicubic spline interpolator module in Compugrid was used in all the SMA surveyed except for Area 12IN where the sector interpolation module of Compugrid was used. These interpolators do not provide any estimate of uncertainty around the biomass index and as a result only point estimates are presented.

Steps have been taken to maintain consistency in methodology, fishing gear, and effort from the start of the surveys in 1998 to 2002. All tows were 30 minutes in duration, unless shortened due to technical difficulties. A 17.7 m high-rise otter trawl, fitted with a Nordmore fish exclusion grid and 1.7 m Whitewater combination trawl doors was used for all the surveys except for the SMA Fraser River survey in 1998. Because the catch efficiency of the trawl net with and without a fish excluder has not been tested no adjustment has been made to the data. All industry supported surveys were carried out using the DFO research vessels "Caligus" and "Neocaligus". The gear used in the surveys was selected based on advice from industry.

For in-season management of the shrimp trawl fishery the indices of shrimp biomass are treated as estimates of the true biomass. All estimates of biomass are standardized to the start of the survey year by summing the biomass index estimated from the survey with commercial catch from start of survey year to the survey date. Once a total biomass is estimated in-season for a given SMA the commercial shrimp catch ceiling for the area is adjusted based on applying a fixed harvest rate to the biomass estimate. A 33% harvest rate is applied to most areas except SMA Fraser River where stocks are considered depressed and a 25% HR is applied.

2.2.2 Indirect Estimation Procedures

For two of the SMA's, 3IN and 14, estimates of shrimp abundance were obtained through extrapolation procedures using fishery independent surveys in adjacent areas. The PRD survey is used as the index site for estimating biomass in 3IN, and the GSTE survey is used as the index site for estimating shrimp biomass in SMA 14. The index sites for each of the areas were selected based on the observed positive correlation of pink shrimp CPUE between the survey site and the unsurveyed site (DFO 1999b, 1999c). Estimates of pink shrimp biomass B_p are extrapolated as follows:

$$B_p = U_p/U'_p * D * A$$

Where U_p is the pink commercial CPUE in the area to be estimated, U'_p is the pink commercial CPUE in the surveyed area, D is the density of pink shrimp in the surveyed area, and A is the area of the fishing grounds in the unsurveyed area.

No significant correlation was observed between sidestripe catches in the surveyed site area and the unsurveyed site. The sidestripe shrimp biomass B_s was therefore estimated from the ratio of sidestripe shrimp CPUE and pink shrimp commercial CPUE as follows:

$$B_s = U_s/U_p * B_p$$

Where U_s is the commercial sidestripe shrimp CPUE and U_p is the commercial pink shrimp CPUE and B_p the estimated pink shrimp biomass in the unsurveyed area calculated above (DFO 1999b, 1999c).

3.0 Results and Discussion

3.1 Historical Catch Reporting

Each of the catch reporting mechanisms in place for the shrimp trawl fishery answer the basic questions of who fished, what was caught, where was it caught, when was it caught and how was it caught. Although similar questions are asked and answered within each of the reporting frameworks, the level of detail varies (Table 1). The variation is driven by the differing primary information needs of the departmental branch

that implemented the given catch reporting program. At the inception of the sales slips system, Markets and Economics Branch sought to provide fishery statistics, including landed value estimates. Science Branch required detailed species, effort and gear information for stock assessment purposes. Fish Management Branch needed to be able to monitor levels of activity and catch in-season, view the fishery in light of the set area quotas and take appropriate, timely action in the event that catch ceilings were achieved.

The purpose in introducing the multiple sales slip system was to provide catch statistics which met the needs of a broad audience, including government, industry and science, while at the same time reducing the amount of paperwork required of industry. Inherent in serving a broad audience is the compromise of detailed information. The annual reports are recognized as a valuable time-series of information, however, as a source of information with which to conduct assessments of shrimp stocks, a number of shortcomings are apparent. After the first year of the program, shrimp species were pooled, with only prawn identified separately. The ability to identify a shift from traditional pink fisheries to other species over time was lost. Only the most basic distinctions between gear types were made; trap versus trawl. There was no accounting for the differences between post-beam gear configurations and otter trawl configurations, all trawl types were treated as equal. Effort information was reported as number of days, with no distinctions between actual fishing days/time and travel days to and from the grounds. Fishing districts and areas were taken from the definitions of the day and have not kept pace with more recent distinctions of inshore and offshore areas, with regard to the management areas, sub-areas and surfline defined in *Pacific Fishery Management Area Regulations.* The ancillary information originally contained within the forward of the publication, critical to gaining an understanding of events which may have lead to patterns within the data, were removed. Finally with the major format change implemented in 1996, the data time-series was interrupted. The ability to monitor landings and landed value by gear type, by area, by month was removed from the publication. The raw data remain available to DFO staff through direct request to the Regional Catch Unit staff.

The data collected under the voluntary logbook program began to address some of the shortfalls of the sales slip data as it pertained to conducting stock assessments. Species specific information was now available and could be used in conjunction with highly resolved effort information (minutes of tow time) and location information (geographic co-ordinates for each tow). However, the variability in number of vessels participating in the program brought into question how representative the data were. Use of voluntary logbook data as a source of assessment information was restricted to applications where other research data were also available.

The mandatory logbook program implemented in 1987 moved to address the question of how representative of the commercial fishery the logbook data were. Since 1987, the annual number of vessels reporting has ranged from a low of 130 (2002) to a high of 222 (1996). There is now a 15-year time series of data containing detailed catch, location and effort information. The mandatory logbook program, well suited to the assessment needs of Science Branch, did not meet the needs of Fish Management Branch, as the data were not available in a timely enough manner for use in-season.

The hail and landing record programs were designed and implemented in 1997 to provide the level of detailed information required for in-season fishery management. From an assessment standpoint, these programs provided less detail regarding both gear and effort than did the mandatory logbook program. As the landing record program was designed also with the intent to replace the sales slip program for shrimp trawl, some of the data items were developed with a view to fit into the old sales slip model. The hail and landing record programs introduced the use of shrimp management areas (SMA's). Use of these data as a time series must be with care as the SMA definitions have undergone modification since their inception. SMA's were introduced June 1997 and defined with reference to Pacific Fishery Management Areas (PFMA's) and sub-areas (Table 2, Fig. 2 and 3). Effective for the 1999 season, several SMA definitions were altered. The definition for SMA Queen Charlotte Islands (QCI) was changed to include only PFMAs 102 and 142. A new SMA, 2IN was established which was comprised of PFMA 2. PFMA 16 was removed from SMA GSTE and established as a separate SMA 16. PFMA 7-25 was removed from SMA 7IN and added to SMA QCSND.

When interpreting data from any of the catch reporting programs discussed above, the question of completeness of the data set will invariably arise. In the absence of third party, 100% observer coverage and/or 100% validation of landings, it is not possible to know if all catch has been reported. Comparisons between data sets to establish compliance levels are onerous. Difficulties in comparing the different data sets result from the differences in resolution of the data components. Sales slips will often account for product sold to established buyers but not product lost through handling and processing or product sold through a private sale. Catch weights reported on harvest logs and landing records are estimates, the accuracy of which varies with the skill and experience of the fisher. Species specific information is dependent on the skill of the operator in identifying and sorting the catch. Any location information must be viewed with the knowledge that the maps used by industry, showing PFMA's and sub-areas, are difficult to interpret. With the removal of Global Positioning System (GPS) selective availability in 2000, the accuracy with which common GPS instrumentation reported latitude and longitude of fishing locations increased 10 fold. For data collected prior to this, location information must be interpreted with care. The most consistent record of catch that incorporates the current spatial and species specific resolution of the shrimp trawl fishery is from the logbook data commencing in 1987 (Fig. 4).

Based on the catch information available, catches in most areas have been extremely variable (Boutillier 1996, Boutillier and Joyce 1998, Convey *et al*. in prep.). The most apparent trend in recent landings, however, has been a large increase after 1994 (Convey *et al*. in prep.)(Table 3). Landings are presented here by Pacific Fisheries Management Area (PFMA) because they were collected to this level of resolution by sales slips, and because definitions of Shrimp Management Areas (SMAs) have changed over time and do not correspond to combinations of entire PFMAs (Fig. 1, 2, & 3). Increased landings were associated with large increases in effort after 1994.

In the North Coast, average landings increased from 63 t between 1982-1994 to 926 t from 1995 to the 2000/2001 season (Table 4). Every PFMA exhibited an increase in average landings except PFMA 1. The most dramatic increases were in PFMA 8 (301 t from 2 t), PFMA 4 (290 t from 36 t) and PFMA 7 (123 t from 1 t).

A similar trend was seen on the east coast of Vancouver Island, where average catches increased in all areas except PFMAs 17 and 28 (Table 5). Average landings from PFMA 11-19, 28 and 29 more than doubled after 1994, increasing from an average of 268 t to 745 t. The most dramatic increase was in PFMA 12 (193 t from 5 t).

Boutillier (1996) and Boutillier and Joyce (1998) documented long-term catch data for four major inshore shrimp trawl areas (PFMA 4, 14, 17 and 28/29). All had peaks in production prior to the most recent increases after 1995. PFMA 4 experienced peak landings in 1963 (160 t) and only exceeded 125 t once, in 1969, until 1995 (Boutillier 1996). Since then, catches have ranged between approximately 200 and 500 t per season (Convey *et al*. in prep.). PFMA 14 produced 131 t in 1965 (Boutillier 1996), then did not exceed 100 t until the early 1990s (Convey *et al*. in prep.). The current record high catch for PFMA 14 is 159 t in the1999/2000 season. PFMA 17 produced 327 t in 1957 (Boutillier 1996), and produced approximately 200-240 t only 4 times (1953, 1956, 1967 and 1968). Landings since 1968 have generally been well below 100 t, and have declined steadily since 1992 (Convey *et al*. in prep.). PFMA 28/29 had its peak production in 1957 (443 t) but did not exceed 160 t from 1964 to 1983, and only exceeded 300 t once thereafter, in 1996 (Boutillier 1996, Convey *et al*. in prep.). Obviously, the decision of which time period to use as "average historical catch" would be very difficult to approach objectively.

3.2 Arbitrary Catch Ceilings

In response to increased effort in the shrimp trawl fishery, and limited stock assessment information, arbitrary catch ceilings were assigned to the various SMA's commencing in the 1997/98 fishing season (Table 8). Areas with no history of shrimp fishing were assigned catch ceilings of 10 t, areas with a history of shrimp fishing were assigned ceilings based on area specific information. A detailed description of how the arbitrary catch ceilings were developed for each area is available in Southey *et al*. (2002).

3.3 Shifts in Commercial Fishing Practices

When catch ceilings were originally set for unassessed shrimp stocks harvested by the commercial shrimp trawl fishery there was an underlying assumption that the species and size composition of the catch would equal that of the vulnerable stock. This underlying assumption appears to be no-longer valid. There is evidence of species and size specific targeting.

3.3.1 Species and Size Specific Targeting

We defined the targeted species of a tow as the shrimp species that made up the greatest component of the catch in terms of weight. The logbook form does not require fishers to identify the target species of each tow. The proportion of the total coast wide shrimp tows targeting sidestripe shrimp was relatively stable from 1978 to 1999, except for 1997 when a single year increase was observed. A recent increasing trend in the proportion of tows targeting sidestripe has occurred from 2000 to present (Fig. 5). Comparison of trends for humpback or coonstripe shrimp could not be carried out due to the limited time series of species specific humpback and coonstripe catch information. However, Dunham *et al*. (2002) indicate a recent trend towards species specific targeting of humpback shrimp.

Pink shrimp are the dominant species in the total coast wide catch of shrimp. The proportion of the total annual catch comprising the two species of pink shrimp averaged approximately 0.97 from 1987 to 1996. A decreasing trend has occurred from 1997 to present and catch data to date indicates that the pink shrimp catch was approximately 84% of the total catch in 2002 (Fig. 6). Conversely sidestripe shrimp as a proportion of the total catch has shown an increasing trend from 1997 to present (Fig. 6).

On-board sampling and discussions with fishers has revealed a recent trend towards size specific targeting for larger shrimp. Results from a bycatch observer revealed selective targeting of coonstripe shrimp and on-board sorting for size. The mean carapace length of captured coonstripe from each of the tows averaged 19.8 mm whereas the mean carapace length of retained coonstripe averaged 25.2 mm (Appendix 3). Of the total coonstripe shrimp catch from this vessel only 48% was retained.

In response to low prices for pink shrimp fishers are finding new markets for the larger shrimp and are moving towards size specific targeting. This size specific targeting is being accomplished through redesign of fishing gear (Commercial shrimp fishers, pers. comm.) and through on-board size sorting of catch.

One of the implications of targeting and using catch ceilings based on historical catch is that for many areas, catch ceilings are a pool of all species. If the total catch ceiling is taken from one species, harvest rate for that species is likely to be well above sustainable levels. Furthermore, with size selective targeting of the largest shrimp occurring within the fishery there is a great potential for the total catch ceiling to be taken from the oldest age class which due to the protandric hermaphoditic life history is the female component of the stock.

3.4 Trends in Shrimp Biomass

Annual point estimates of shrimp biomass are available from each of the 9 survey areas which include SMA PRD, 12IN, 12OUT, GSTE, 16, 18, 19 FR, and 23IN. The fishery independent surveys estimate species specific biomass. For the purposes of this paper we have combined the spiny pink (*Pandalus borealis*) and smooth pink (*Pandalus jordani*) estimates of biomass into a "pink" biomass to facilitate the comparisons with fishery dependent data, which are not recorded to species level for pink shrimp. However, it is important to recognize that the species specific composition of the estimated pink shrimp biomass can fluctuate annually. The area showing the greatest fluctuation is SMA 16 where the proportion of spiny pink shrimp has ranged from .08 to .53 of the total pink shrimp biomass (Fig. 7). Spiny and smooth pink shrimp also occur together in SMA's PRD and 12OUT (Fig. 7).

Pink shrimp biomass in surveyed areas from 1997 to 2002 has generally been variable and without trend (Fig. 8a, Table 6). However SMA 23IN has shown an increasing trend in pink shrimp biomass from 1999 to 2001. Decreasing trends have been observed in SMA's 3IN, 18 and FR. Pink shrimp biomass in SMA FR decreased significantly in 2002.

Sidestripe shrimp biomass was also variable and without trend (Fig. 8b, Table 6). SMA 18 has shown a decreasing trend while neighbouring SMA 19 has shown an increasing trend in sidestripe biomass. Sidestripe biomass in SMA FR decreased significantly in 2002.

The greatest fluctuation in pink shrimp biomass from 1998 to 2002 was observed in SMA 19 and the least fluctuation in SMA 16 (Coefficient of Variation (CV) = 122% and 20% respectively; Table 7, Fig. 8a). The greatest fluctuation in sidestripe shrimp biomass was observed in SMA 14 and the least in SMA's PRD and FR (CV= 113% and 21% respectively, Table 7, Fig. 8b).

These 5 years of biomass estimates are too short a time series in terms of detecting long term trends. This 5 year time series only covers one generation which is insufficient to define a period of no decline for evaluating the application of historical catch as a proxy for abundance.

One of the weaknesses in the fishery independent indices of biomass as presented is that only point estimates are provided and as such they do not contain any measure of uncertainty or sample variability. Work is progressing on developing measures of uncertainty around the biomass estimates. Data analysts within the Shellfish section are currently testing other spatial interpolators that have a variance component.

3.5 Shrimp Biomass Estimated through Extrapolation Procedures

Shrimp biomass in SMA's 3IN and 14 has been indirectly estimated through extrapolation procedures starting in 1999. Pink and sidestripe shrimp biomass in these two SMA's has been variable over the 4 years indices are available. The reliability of these indices of biomass is unknown. Again these indices assume that CPUE in the survey area and the non-survey area are indicators of stock size and that fishing practices are similar in both areas. If targeting of a particular species is more prevalent in one area than the other this would likely invalidate the use of this extrapolation procedure.

4.0 Conclusions

The shrimp trawl fishery off the west coast of British Columbia is in a state of dynamic change. The implementation of fishery independent surveys of shrimp biomass by the Stock Assessment Division (and partially funded by industry) has allowed for systematic monitoring of stock status even during the changing fishery. These surveys form the foundation for providing credible stock assessment advice to ensure stock conservation to manage harvest. With this information mangers have moved towards setting species and area specific quotas. Prior to the implementation of fishery independent surveys of shrimp biomass no catch ceilings were imposed.

Use of catch data alone to set reference points, or more specifically total allowable catches (TACs) has been discussed in the context of situations where no other information is available. The primary caveat to the use of these data is that the catches occur during a period in which no decline in stock can be demonstrated. Early catch data (1951-1987) have no resolution to species and have no supporting stock assessment information that would provide assurances that stocks did not decline during this period. Catches during the expansion phase of the fishery (1987-2002) may not be sustainable; history has proven that they rarely are (*e.g.*, Caddy and Gulland 1983, Gunderson 1984, Francis 1986, Hilborn and Sibert 1988, Hilborn and Walters 1992, Gillespie and Bond 1997). In this case, however, lack of sustainability may be due to highly variable stock size and uncertain responses of virgin stocks to fishing pressure, rather than depletion of accumulated biomass in longer-lived animals. As well, this period is one of rapid change in catch composition, both in regard to species and age class. The fishery is not in a "steady-state" phase, and therefore average catches from this period are not particularly informative, and may be misleading if used indiscriminately.

The use of historic catches to set TACs has some benefits: it is relatively inexpensive, requires little analytical effort and is intuitively attractive to fishers (Table 8). On the negative side, it allows only for reactive decision making, provides no new information on stock size and status (catches do not track abundance as they are affected by other extrinsic factors such as markets, prices, etc.), and presents risk of over-harvest of stocks in low abundance years and under-harvest in high abundance years.

The use of directed assessment surveys to set TACs has a number of benefits: surveys measure species specific stock size and status directly, provide information needed for setting age/size specific quotas, provide new information to a growing information base upon which to base decisions, allow those decisions to be proactive (including information on current stock size and status), utilize decision rules and multiple information sources, and allow variable TACs which are conservative in years of low abundance and allow for larger harvests in years of high abundance (Table 8). This framework's primary detractions are that it is expensive, and complex. The system is not easily understood by fishers, which makes consultation and co-management difficult.

We have seen shift from non-selective harvesting in terms of shrimp species and size to species and size specific targeting. This shift has resulted in challenges for both management and assessment of shrimp stocks, particularly in the setting of appropriate catch ceilings. When setting catch ceilings/harvest rates consideration has to be given to the ability of the fleet to potentially harvest the entire quota from a single age class. The previous assumption used when setting the harvest rate (and catch ceiling) was that the commercial fleet would harvest the various age classes in proportion to the population abundance. This assumption is no longer a valid.

With the current fishing practices the fleet has the ability to target a species specific age class. Many of the SMA's for which we have no fishery independent estimates of abundance or developed a suitable method of indexing abundance have combined species catch ceilings set at an arbitrary 10 t. In light of the change in the fishery these 10 t ceilings may no longer be conservative or "risk averse". If the entire quota was removed from the single age-3 age class of a particular species the harvest could likely result in the removal of the entire female spawning population, which is well above the sustainable harvest rate of 33% determined for shrimp stocks (Boutillier *et al*. 1999, Martell *et al*. 2000).

Another major concern with setting catch ceilings based on historical catch is the negative impact this type of harvest management practice has on the "weak" shrimp stocks. For example, humpback shrimp are harvested incidentally in the trawl fishery and because the biomass of humpback shrimp is often orders of magnitude smaller than the targeted population the resulting harvest rate on the "weak" stock can potentially be very large. Conservation and sustainable harvest of weak stocks cannot be ensured by establishing catch ceilings from historical catch records of pooled species data.

The assessment framework (survey methods, forecasting and extrapolation) has been in use for all of B.C. since 1998, and continues to be developed and improved. The program clearly meets requirements for informed management based on the best available scientific information and advice, and follows the Precautionary Principle.

Although the focus of this paper centres on the utility of the historical shrimp catch data to set harvest reference points and the benefits of the fishery independent surveys, it is also important to recognize that stock assessment does not simply involve carrying out a survey, reporting biomass and recommending appropriate harvest rates. Stock assessment involves collecting time series information on abundance, species and age composition, and many other parameters needed to understand shrimp stock dynamics and in particular recruitment parameters. Stock assessment information is essential to ensure long term sustainable harvest, conservation of shrimp stocks and to address and respond to ecosystem concerns. Any gap in this developing time series severely hinders StAD's ability to analyse data and provide credible assessment advice and compromises the Departmental mandates to insure conservation and sustainable utilization.

The suggestion to abandon fishery independent surveys and use "historical" catch as a replacement for setting reference points is **NOT** a viable option for ensuring conservation of shrimp stocks and sustainability of the industry considering the nature of this fishery on mixed species of animals which can be selectively targeted to put the entire female component of the stock at risk.

5.0 Recommendations

1. Commercial shrimp trawl catch data should not be used as a proxy for shrimp abundance in reference point models.
2. Continue collecting fishery independent data to monitor shrimp stock abundance.
3. Continue using fishery independent estimates of shrimp abundance in reference point models.
4. Continue to investigate the utility of using survey sites to index shrimp abundance in "non-surveyed" SMA's
5. When setting catch ceilings recognize the ability of the shrimp trawl fleet to target species and age/size specific components of the shrimp population.

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Table 1.Differing levels of detail in common components of shrimp trawl catch monitoring and reporting programs.

	Identification	Species	Effort	Gear	Location	Time Series available	Submission timeframe	Value ($'s)	Branch responsibility
Multi-part Sales Slip	vessel registration number	pooled	days fished	trawl or trap	statistical areas (no inshore/ offshore distinctions)	1951 to 1995; 1996 to present	within 7 days of offload	yes; buyers identified	Economics; Corporate Services
Voluntary Harvest Logs	vessel registration number	species specific	minutes towed	trawl gear configuration classes	tow by tow co-ordinates	1975 to 1986	unknown	no	Science
Mandatory Harvest Logs	vessel registration number; vessel master	species specific (pooled pinks)	minutes towed	trawl gear configuration classes	statistical areas and sub-areas with inshore/ offshore distinctions; tow by tow co-ordinates post 1997	1987 to present	within 28 days following end of month of fishing	no	Science
Landing Records	vessel registration number; vessel master	species specific (pooled pinks)	days fished	trawl beam vs. otter	shrimp management areas	1997 to 2002	within 48 hours of offload	yes; buyers identified	Fish Management
Fishing/ Landing Hails	vessel registration number; vessel master	species specific (pooled pinks)	days fished	trawl beam vs. otter	shrimp management areas	1997 to present	prior to trip commencing; again prior to offload	no	Fish Management

Table 2. Shrimp Management Area designations effective April 1, 1997 to March 31, 1998 in relation to Pacific Fishery Management Areas.

SMA	Pacific Fishery Management Areas
DXE	1, 101
QCI	2, 102, 142
3IN	3-5 to 3-16
PRD	3-1 to 3-4, 103, 4-1 to 4-6, 104, 5-1 5-2, 5-23
5IN	5-3 to 5-10, 5-12 to 5-19, 5-21, 5-24
5OFF	5-11, 5-20, 5-22, 105
6IN	6-1 to 6-8, 6-10 to 6-12, 6-14 to 6-16, 6-18 to 6-28
6OFF	6-9, 6-13, 6-17, 106
7IN	7-2 to 7-25, 7-27 to 7-30
8IN	8-2 to 8-16
9IN	9-1, to 9-12
10IN	10-3 to 10-12
QCSND	107, 7-1, 7-26, 7-31, 108, 8-1, 109, 110, 10-1, 10-2, 111, 11-1, 11-2, 130
11IN	11-3 to 11-10
12IN	12-22, 12-23, 12-26 to 12-48
12OUT	12-1 to 12-21, 12-24, 12-25
GSTE	13, 15, 16
14	14
17	17
18	18
19	19
20	20
FR	28,29
21OFF	121, 21
23IN	23-1 to 23-6
23OFF	123, 23-7 to 23-11
24IN	24
124OFF	124
125OFF	125
25IN	25
26IN	26
126OFF	126
27IN	27-3, 27-7 to 27-11
27OFF	127, 27-1, 27-2, 27-4 to 27-6

Table 3. Annual shrimp trawl landings (t), effort, landed value and mean catch per unit effort (CPUE), 1982 to 2000/01 (Convey *et al*. in prep.).

Year		Number of Eligible Licences	Number of Vessels with Landings	Fishing Effort (days)	Shrimp Landings (t)	Total Landed Value ('000's $)	Whole Landed Value ($/kg)	Mean CPUE (t/day)
1982		249	N/A	4,230	398	863	2.17	0.09
1983		249	120	8,076	411	1,095	2.66	0.05
1984		249	114	6,783	408	1,022	2.50	0.06
1985		249	102	6,337	678	1,180	1.74	0.11
1986		249	102	5,580	768	1,240	1.61	0.14
1987		249	165	9,027	2,643	4,609	1.74	0.29
1988		249	190	6,763	2,561	3,248	1.27	0.38
1989		249	174	6,982	2,299	2,838	1.23	0.33
1990		249	173	6,360	1,940	2,637	1.36	0.30
1991		249	185	7,564	3,265	4,430	1.36	0.43
1992		249	162	6,123	2,683	3,499	1.30	0.44
1993		249	158	6,139	3,283	3,499	1.07	0.53
1994		249	165	7,311	3,192	4,776	1.50	0.44
1995		249	216	14,331	6,778	13,663	2.02	0.47
1996		249	222	16,246	7,386	11,001	1.49	0.45
1997a	*	248	93	N/A	285	N/A	N/A	N/A
1997/98	**	248	181	N/A	3,255	5,262	1.62	N/A
1998/99	***	248	191	11,351	3,493	5,767	1.65	0.20
1999/00	***	249	198	11,180	2,646	4,167	1.82	0.20
2000/01	***	249	165	14,793	2,396	4,047	1.69	0.16

* 1997a data from Sales Slips (Jan 1/97 - Mar 31/97), Area Quotas were introduced in 1997 and the new season runs from April to March.

** 1997/98 data from Apr. 1/97 - Mar. 31/98. Sales Slips (Apr 1 - June 17) Landing Records (June 18 - Mar. 31/98)

*** Data from Landing Records (Apr 1 to Mar 31).
2000/2001 data is preliminary (total landings combined from area totals)

Table 4. Annual shrimp trawl landings (t) by North Coast Pacific Fisheries Management Areas, 1982 to 2000/01 (Convey *et al*. in prep.).

	NORTH COAST MANAGEMENT AREA											
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	Unknown	**Annual Landings**
1982	2.6	0.0	1.4	20.3	0.4	0.0	0.0	0.0	0.3	0.0		25.0
1983	1.9	#	1.7	11.4	#	1.2	0.0	0.0	#	#		19.7
1984	5.7	#	#	8.8	8.5	4.7	0.6	1.8	0.0	0.0		31.5
1985	3.0	#	2.5	15.8	11.9	#	0.0	#	#	0.0		34.3
1986	#	1.4	4.2	27.3	11.3	0.8	0.9	1.3	#	0.0		49.0
1987	5.9	1.7	2.6	19.7	6.9	7.6	#	1.1	#	#		47.5
1988	1.0	3.1	3.2	10.9	7.3	1.9	#	0.6	#	1.7		31.1
1989	3.0	#	0.6	29.7	5.2	3.7	2.5	6.4	3.7	7.3		63.5
1990	2.5	#	4.0	91.2	8.2	24.2	0.5	1.2	0.1	0.3		132.6
1991	3.6	7.7	2.4	75.8	7.4	6.0	0.7	0.8	2.2	2.6		109.2
1992	#	#	3.2	52.8	12.5	#	3.7	4.2	3.7	#		91.5
1993	2.9	#	8.2	46.9	7.3	1.7	2.1	3.1	0.2	#		77.3
1994	22.5	#	#	61.1	6.6	6.2	0.7	0.3	#	0.2		101.5
Avg 1982-1994	4.5	1.5	2.7	36.3	7.4	4.5	0.9	1.6	1.3	1.9		62.6
1995	0.8	4.8	9.0	198.4	18.1	23.0	0.8	11.8	11.9	2.1		280.5
1996	10.6	0.7	16.7	507.1	51.7	27.4	251.1	911.4	12.6	32.0		1821.3
1997a*	0.0	0.0	8.3	23.9	7.1	0.0	0.3	0.0	0.0	0.0		39.6
1997/98**	0.2	0.4	31.0	136.2	41.0	11.2	144.1	414.1	16.9	85.6		880.9
1998/99***	0.0	19.2	9.1	227.7	19.8	28.8	333.7	459.5	96.1	30.4	213.4	1437.9
1999/2000***	0.0	15.0	93.3	441.2	57.6	14.8	5.8	#	67.4	10.7	32.8	745.0
2000/2001	0.0	#	68.5	213.5	46.1	9.3	2.2	#	18.3	#	6.7	393.0
Avg 1995-2000/01	1.9	8.1	38.3	289.6	39.1	19.1	123.0	300.6	37.7	26.8		926.4

Notes: 1. Data from 1997a were not included in the 1995-2001 average landings.

* 1997a data from Sales Slips (Jan 1/97 - Mar 31/97), New fishing year is April to March under quota management.

** 1997/98 data from Apr. 1/97 - Mar. 31/98. Sales Slips (Apr 1 - June 17) Landing Records (June 18 - Mar. 31/98)

*** 1998/99 data from Apr.1/98 to Mar. 31/99 all from Landing Records.

 # Landings do not meet confidentiality requirements.

Table 5. Annual shrimp trawl landings (t) by South Coast Pacific Fisheries Management Areas, 1982 to 2000/01 (Convey *et al*. in prep.).

	SOUTH COAST MANAGEMENT AREAS												
	East Coast Vancouver Island												East Coast
Year	11	12	13	14	15	16	17	18	19	28	29 Unknown		Landings (t)
1982	0.0	0.4	0.0	18.8	0.0	6.4	20.5	6.1	0.1	53.6	90.6		196.5
1983	#	1.7	#	26.2	#	13.3	70.3	13.1	#	28.1	171.5		324.8
1984	0.0	1.5	#	27.7	0.0	1.3	90.2	4.6	0.7	80.3	120.1		327.0
1985	0.0	2.0	0.4	32.6	#	1.2	60.4	5.3	0.8	60.7	92.9		256.5
1986	#	12.3	3.1	39.7	2.4	4.0	42.1	4.2	1.4	74.8	51.7		235.9
1987	1.1	6.0	1.2	38.5	1.2	7.7	23.7	12.7	#	83.5	78.3		255.4
1988	0.0	6.2	#	49.6	#	#	33.1	8.1	3.2	53.6	114.3		270.9
1989	0.4	3.0	1.3	35.5	13.9	1.7	36.0	8.5	4.5	42.2	91.2		238.1
1990	0.2	12.0	1.9	51.7	#	2.7	15.2	4.5	0.8	13.9	61.4		165.6
1991	0.1	12.4	0.0	77.4	2.3	#	37.0	10.9	0.4	54.6	67.0		262.8
1992	#	1.6	24.3	109.7	46.2	#	39.4	7.4	#	50.5	91.1		371.8
1993	#	2.7	1.1	118.4	42.9	1.5	22.9	5.3	0.1	57.3	86.7		338.9
1994[1]	0.2	0.8	#	78.0	65.7	2.2	15.4	2.5	#	24.4	43.4		235.0
Avg 1982-1994	0.2	4.8	2.8	54.1	13.7	3.4	38.9	7.2	1.1	52.1	89.2		267.6
1995	16.5	71.9	12.3	35.3	52.0	1.9	20.7	14.5	1.7	69.0	85.3		381.2
1996	55.4	546.9	2.5	120.2	69.3	16.0	23.8	195.8	23.1	64.9	283.8		1,401.7
1997a*	1.9	29.7	1.4	32.4	21.6	2.2	0.0	76.0	23.1	0.1	0.1		188.5
1997/98**	43.7	163.8	25.8	93.1	75.4	21.2	16.3	115.1	32.0	61.2	69.7		717.4
1998/99***	11.5	188.5	17.8	90.7	156.5	32.6	11.8	76.6	19.2	51.5	130.9	17.9	805.6
1999/00***	#	110.1	8.4	158.5	68.3	39.6	8.2	52.2	39.8	29.2	80.4	0.9	595.7
2000/01	#	74.4	6.8	114.2	79.2	31.2	8.8	30.4	61.4	30.2	124.9	2.7	565.7
Avg 1995-2000/01	21.3	192.6	12.3	102.0	83.5	23.9	14.9	80.8	29.5	51.0	129.2		744.6

	West Coast Vancouver Island								Total	
									West Coast	South Coast
Year	20	21	22	23	24	25	26	27 Unknown	Landings (t)	Landings (t)
1982	0.5	0.0	0.0	34.5	123.0	0.0	0.0	0.0	158.0	354.5
1983	17.2	10.9	0.0	36.7	0.0	0.0	0.0	#	66.6	391.4
1984	7.0	0.0	0.0	40.9	#	#	0.0	#	50.0	377.1
1985	4.8	#	0.0	304.8	73.1	#	0.0	0.6	387.5	644.0
1986	3.7	#	0.0	288.5	190.4	#	0.0	0.7	483.3	719.2
1987	6.4	0.0	0.0	281.3	2,049.6	1.8	#	0.5	2,340.8	2,596.2
1988	4.7	0.0	0.0	276.9	1,972.0	#	0.0	3.0	2,258.8	2,529.7
1989	13.1	0.0	0.0	310.1	1,660.4	8.9	#	4.2	1,997.1	2,235.2
1990	4.8	#	0.0	302.1	1,330.2	#	0.0	#	1,641.4	1,807.0
1991	9.5	0.0	0.0	989.9	1,658.8	204.2	0.0	30.3	2,892.5	3,155.3
1992	2.6	#	#	136.3	1,009.5	989.9	#	67.1	2,219.7	2,591.5
1993	2.3	0.0	#	293.0	895.9	1,650.9	#	1.7	2,866.5	3,205.4
1994	5.8	#	#	528.9	1,424.3	889.4	#	#	2,856.6	3,091.7
Avg 1982-1994	6.3	1.2	2.1	294.1	952.9	288.7	1.3	8.6	1,555.3	1,822.9
1995	8.5	85.6	0.0	4,155.8	1,413.5	870.8	12.1	37.1	6,583.4	6,964.6
1996	3.2	48.0	3.3	3,205.9	529.2	476.4	7.3	118.0	4,391.3	5,793.0
1997a*	0.0	0.0	0.0	3.9	0.0	48.3	0.0	4.7	56.9	245.4
1997/98**	0.0	33.4	0.0	1,105.5	466.5	48.6	3.1	0.0	1,657.1	2,374.5
1998/99***	0.0	0.0	0.0	936.0	32.3	190.8	11.9	56.0	20.5	1,247.6	2,053.2
1999/2000***	0.1	0.0	0.0	1,090.9	8.5	47.1	#	37.7	1.8	1,213.7	1,809.4
2000/2001	0.0	46.9	0.0	1,164.9	96.5	61.6	0.0	#	59.4	1,438.9	2,004.7
Avg 1995-2000/01	2.0	35.7	0.5	1,944.1	424.4	284.1	6.1	44.8	27.2	2,755.3	3,499.9

Notes: 1. Areas 28 & 29, 1994 catches have been corrected to reflect catch by area based on logbook data.
2. Data from 1997a were not included in the 1995-2001 average landings.

* 1997a data from Sales Slips (Jan 1/97 - Mar 31/97), Area quotas were introduced and the new fishing year runs April to March.

** 1997/98 data from Apr. 1/97 - Mar. 31/98. Sales Slips (Apr 1 - June 17) Landing Records (June 18 - Mar. 31/98)

Table 6. Estimated shrimp biomass, by species and SMA, from 1998 to 2002.

		Pink Shrimp			Sidestripe Shrimp		
SMA	Year	Biomass Index[a] (t)	Catch[b] (t)	Total Biomass Index[c] (t)	Biomass Index[a] (t)	Catch[b] (t)	Total Biomass Index[a] (t)
PRD	1998	799.4	48.3	847.7	355.6	34.6	390.2
	1999	1985.8	89.6	2075.4	604.5	52.8	657.3
	2000	699.4	4.9	704.3	465.1	2.9	468.0
	2001	1019.0	8.0	1027.0	421.0	11.0	432.0
	2002	637.3	1.0	638.3	520.4	5.0	525.4
3IN	1999	155.5	7.3	162.8	99.7	9.6	109.3
	2000	66.6	11.9	78.5	102.0	24.0	126.0
	2001	94.5	7.8	102.3	47.5	8.3	55.8
	2002	47.9	1.4	49.3	69.1	1.7	70.8
12OUT	1998	37.3	2.5	39.8	98.6	4.4	103.0
	1999	31.1	1.9	33.0	43.3	3.2	46.5
	2000	51.9	0.4	52.3	85.5	0.1	85.6
	2001	27.0	0.0	27.0	71.1	0.3	71.4
	2002	61.5	0.0	61.5	64.0	0.2	64.2
12IN	1998	364.6	67.7	432.3	32.1	1.2	33.3
	1999	129.1	23.7	152.8	50.1	0.6	50.7
	2000	295.2	27.5	322.7	47.8	3.2	51.0
	2001	396.5	1.5	398.0	83.9	0.9	84.8
	2002	300.9	0.7	301.6	55.0	0.7	55.7
14	1999	511.5	66.1	577.6	47.5	6.1	53.6
	2000	274.6	74.8	349.4	24.7	6.0	30.7
	2001	267.5	43.3	310.8	26.8	4.3	31.1
	2002	829.2	51.3	880.5	157.9	4.5	162.4
GSTE	1998	504.9	109.1	614.0	167.5	12.3	179.8
	1999	217.4	39.9	257.3	48.8	2.5	51.3
	2000	232.3	15.6	247.9	44.8	1.1	45.9
	2001	571.3	11.0	582.3	91.5	0.5	92.0
	2002	421.3	25.2	446.5	157.9	4.5	162.4
16	1998	96.2	17.8	114.0	44.9	5.4	50.3
	1999	80.1	11.8	91.9	24.5	2.2	26.7
	2000	100.5	18.7	119.2	24.8	1.2	26.0
	2001	98.9	8.8	107.7	28.3	1.6	29.9
	2002	136.0	18.4	154.4	29.4	4.0	33.4
FR	1998	448.4	74.6	523.0	222.5	14.3	236.8
	1999	265.7	36.5	302.2	123.6	129.4	253.0
	2000	445.8	20.8	466.6	179.2	4.5	183.7
	2001	457.0	0.0	457.0	201.0	66.0	267.0
	2002	102.9	0.0	102.9	96.2	0.0	96.2
18	1998	49.8	72.4	122.2	16.3	6.3	22.6
	1999	82.2	17.8	100.0	34.8	1.2	36.0
	2000	164.0	22.9	186.9	15.7	2.6	18.3
	2001	36.6	6.4	43.0	10.5	3.5	14.0
	2002	75.1	16.4	91.5	26.3	1.9	28.2
19	1998	8.3	6.8	15.1	5.9	1.4	7.3
	1999	134.1	0.7	134.8	13.3	0.3	13.6
	2000	589.9	7.6	597.5	16.6	0.8	17.4
	2001	92.8	8.2	101.0	14.8	0.5	15.3
	2002	87.9	16.8	104.7	17.9	1.8	19.7
23IN	1998	148.3	41.0	189.3	11.5	3.2	14.7
	1999	114.0	8.6	122.6	31.0	2.3	33.3
	2000	385.0	0.0	385.0	57.0	0.0	57.0
	2001	955.0	0.0	955.0	82.0	0.0	82.0
	2002	958.0	0.0	958.0	53.0	0.0	53.0

a Biomass index at time of survey

[a] Commercial catch from April 1st to survey date

[c] Total Biomass Index = Biomass Index +Catch

Table 7. Relative annual variability in shrimp biomass, by SMA, expressed as the coefficient of variation.

SMA	Species	N Years	C.V.
PRD	Pink	5	54%
3IN	Pink	4	47%
12OUT	Pink	5	33%
12IN	Pink	5	34%
14	Pink	4	50%
GSTE	Pink	5	40%
16	Pink	5	20%
18	Pink	5	48%
19	Pink	5	122%
FR	Pink	5	46%
23IN	Pink	5	78%
PRD	Sidestripe	5	21%
3IN	Sidestripe	4	35%
12OUT	Sidestripe	5	29%
12IN	Sidestripe	5	34%
14	Sidestripe	4	113%
GSTE	Sidestripe	5	58%
16	Sidestripe	5	30%
18	Sidestripe	5	39%
19	Sidestripe	5	32%
FR	Sidestripe	5	33%
23IN	Sidestripe	5	47%

Table 8. Comparison of directed assessment information versus use of historical catch information to assess and manage shrimp fisheries in British Columbia.

Directed Assessments	Historic Catches
- relatively expensive, requires resources to collect, collate, analyze and interpret assessment data within short time frames	- relatively inexpensive, requires only annual monitoring of catch levels relative to the TAC and occasional re-assessment of catch information to reset TACs
- measures stock size and status directly, provides new information on current stock size and status, builds information base for understanding shrimp stock dynamics	- provides no information other than most recent catch data, possibly supported by qualitative information from fishers; catches do not track abundance (affected by markets, prices, weather and other factors)
- allows for proactive decisions to be made based on stock size and status	- allows only for reactive decisions based on ability to achieve TAC
- relies on decisions rules and multiple information sources to set TACs annually	- only one decision rule, TACs set for longer terms, only revised occasionally
- allows for low TACs to be set in low abundance years, high TACs in high abundance years; reduces risk of over-harvesting depleted stocks or under-harvesting abundant stocks	- TAC not linked to current stock abundance, assumes little variability in stock size and catch composition; does not protect depleted stocks from over-harvest nor allow increased harvest in years of high abundance
- complex and poorly understood, low acceptance by fishers	- intuitive, easily understood and accepted by fishers

Table 9. Arbitrary shrimp catch ceilings set in 1997.

SMA	Species	Initial Catch Ceiling (t)
PRD	all species combined except sidestripes	100.0
PRD	sidestripes	100.0
3IN	all species combined	10.0
12OUT	all species combined	10.0
12IN	pinks	172.4
12IN	sidestripes	6.8
12IN	humpbacks	15.9
14	all species combined	100.0
GSTE + 16	all species combined	100.0
FR	all species combined	90.0
18	all species combined	100.0
19	all species combined	20.0
23IN	all species combined	175.0
14	all species combined	100.0

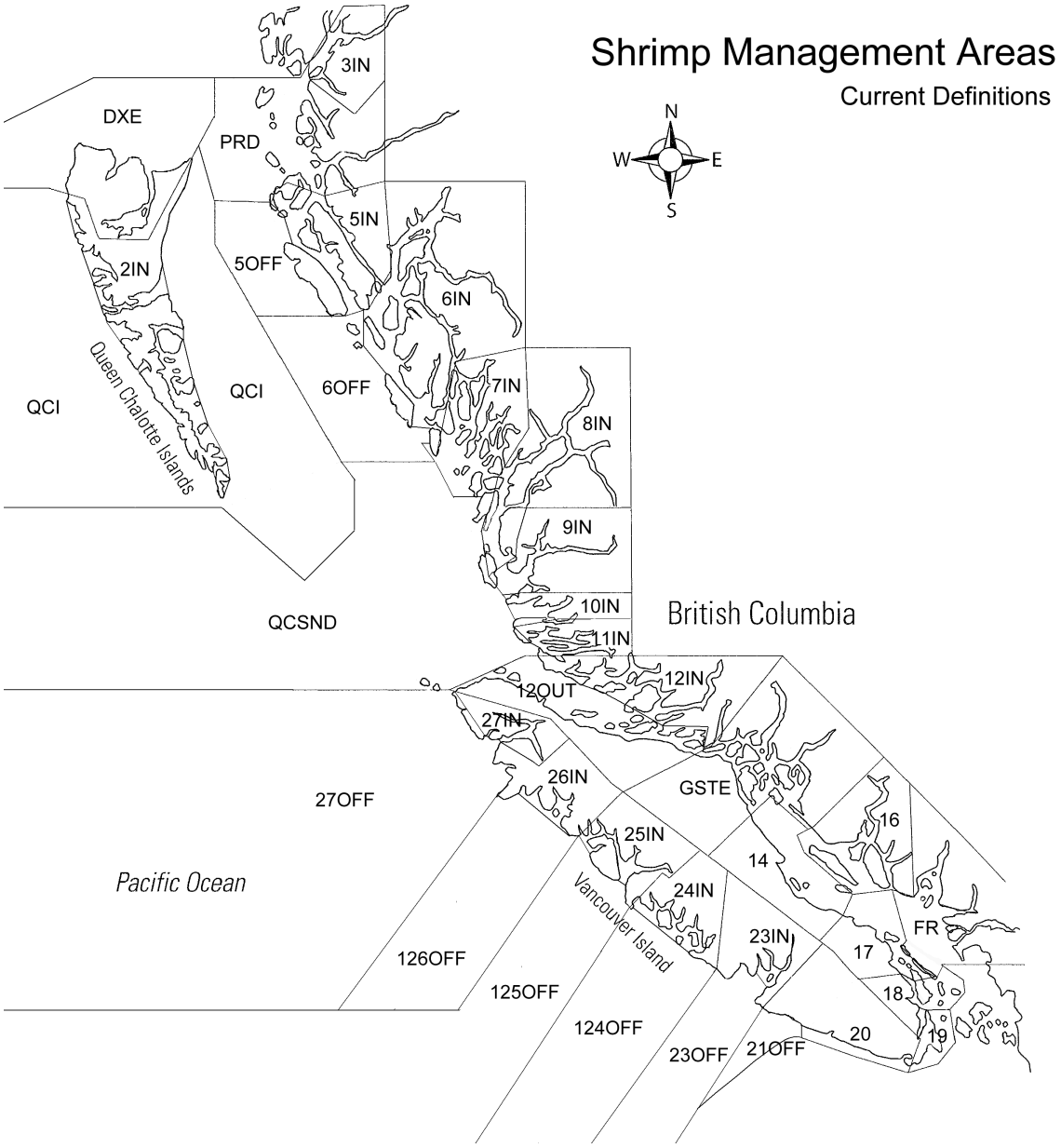


Figure 1. Shrimp Management Areas in use from 1999 to 2003.

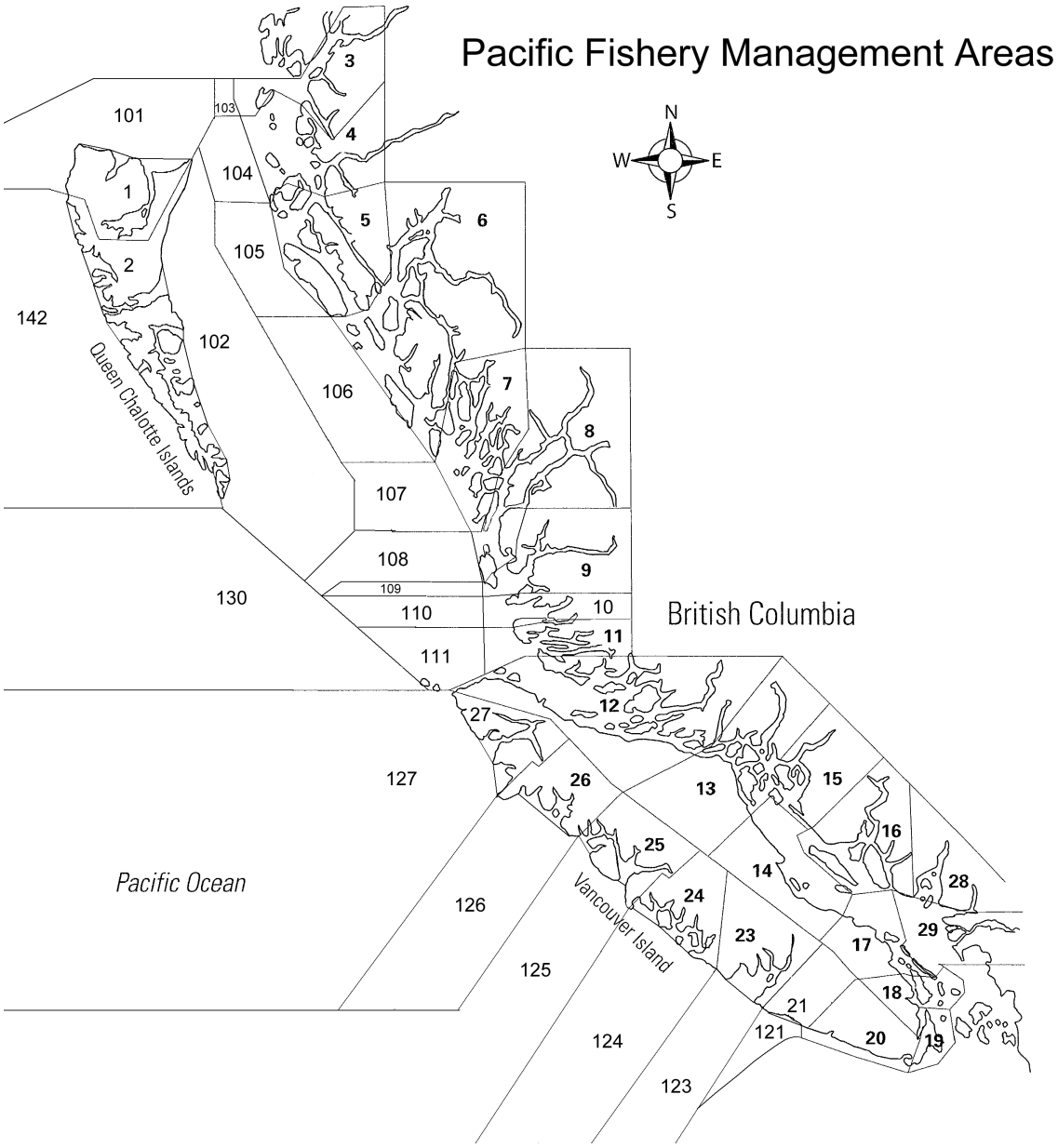


Figure 2. Pacific Fishery Management Areas.

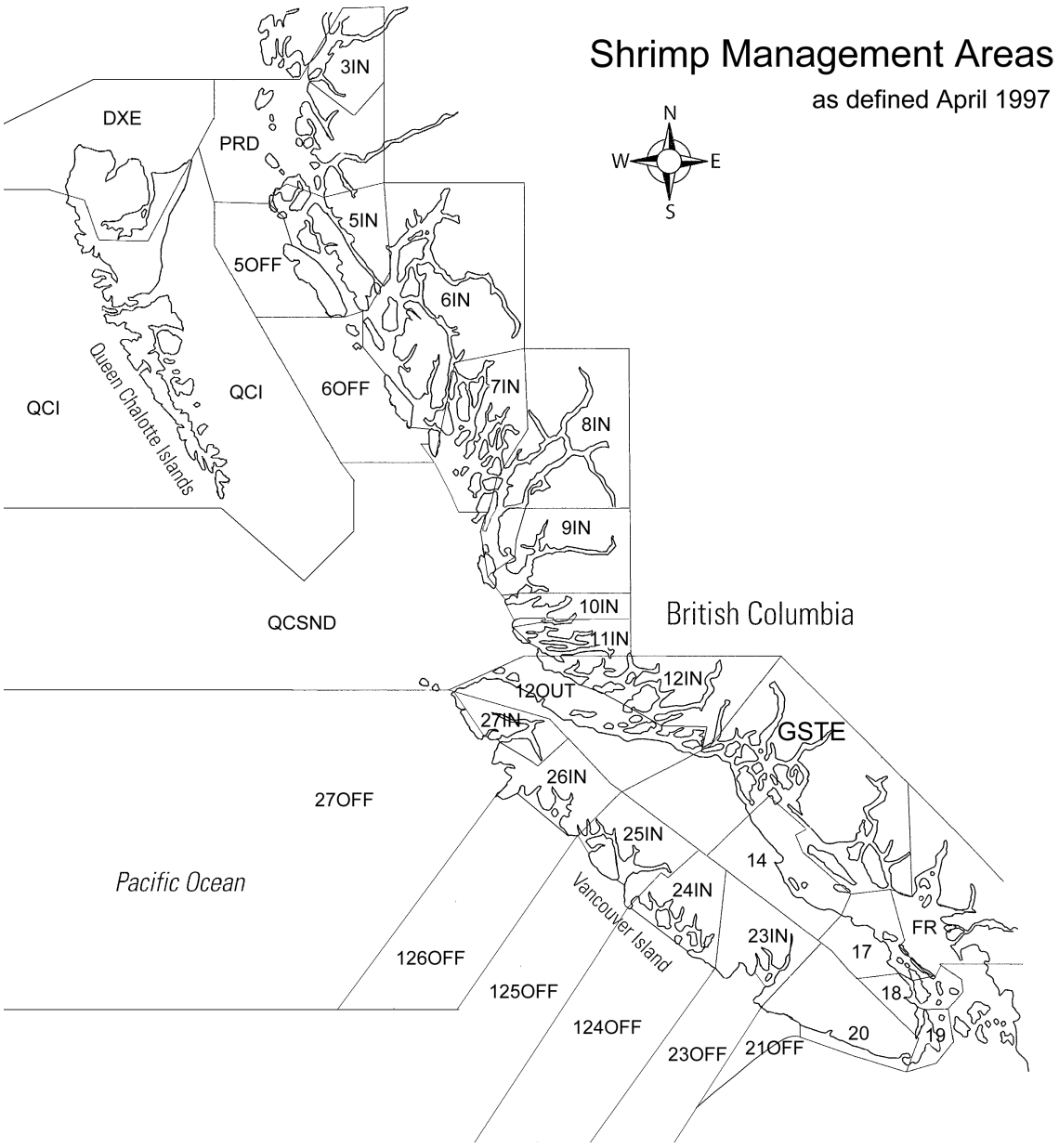


Figure 3. Shrimp Management Areas originally defined in 1997.

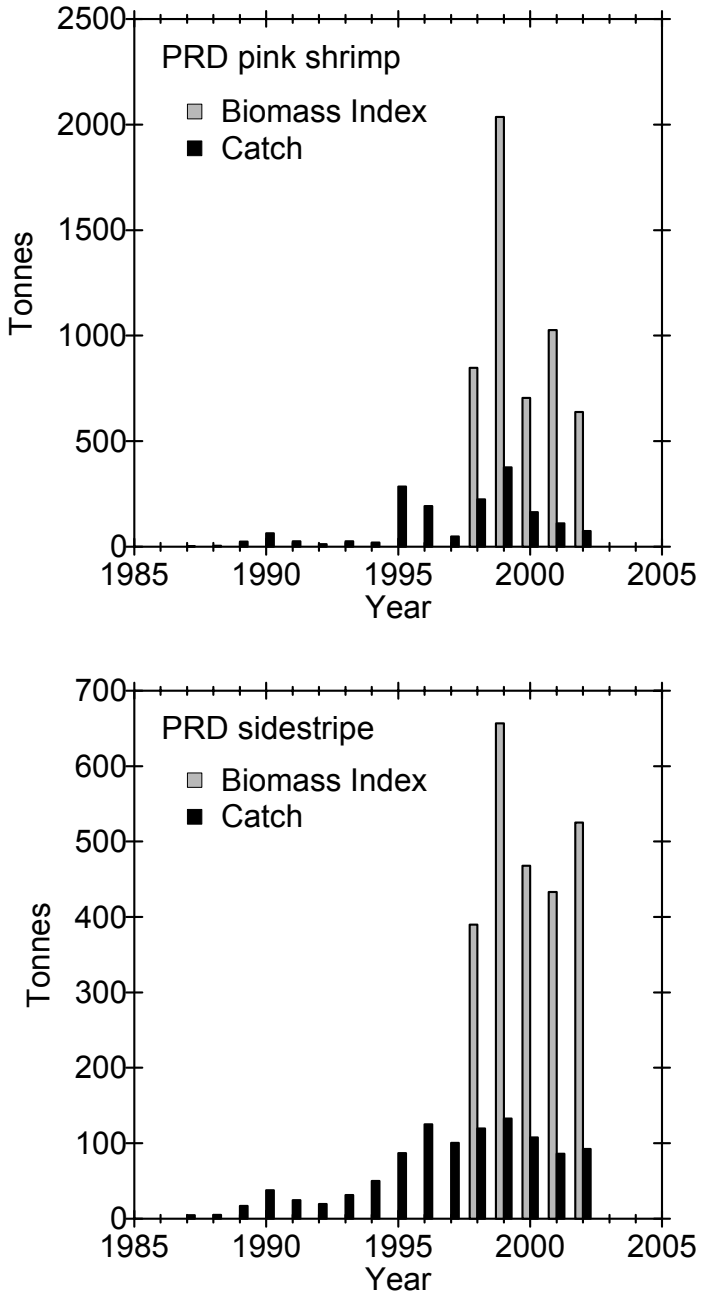
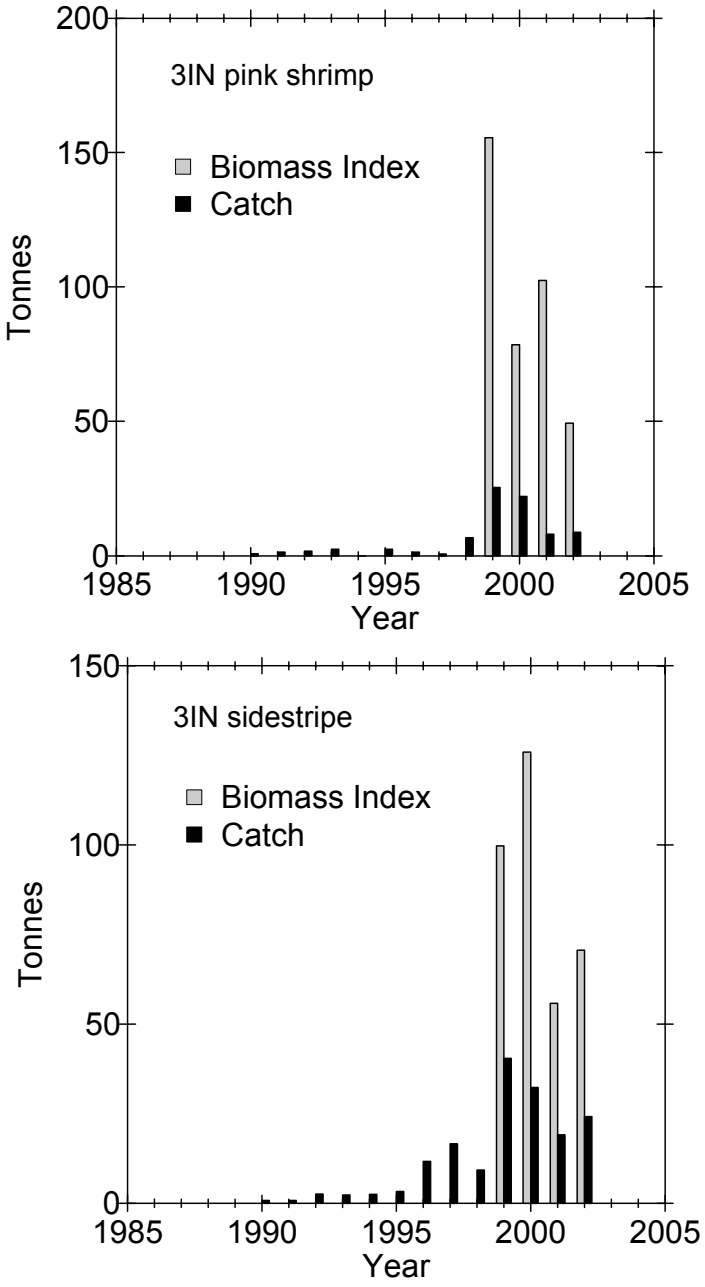


Figure 4. Commercial catch and biomass index for pink and sidestripe shrimp by SMA.



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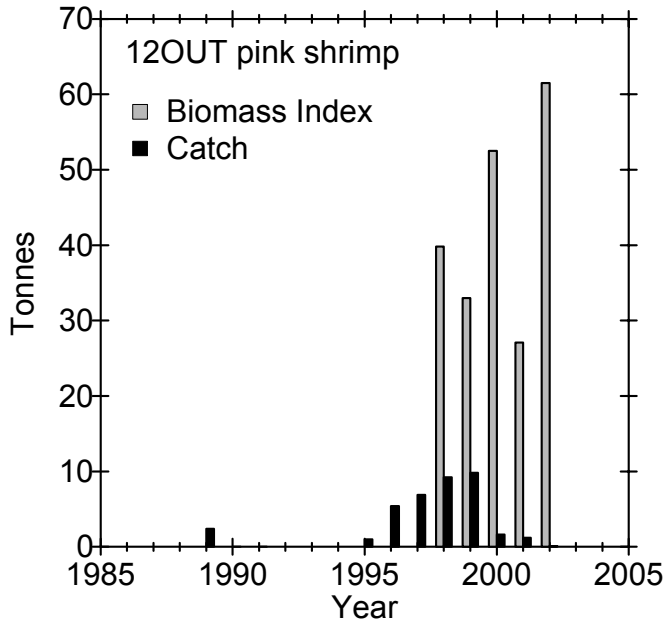

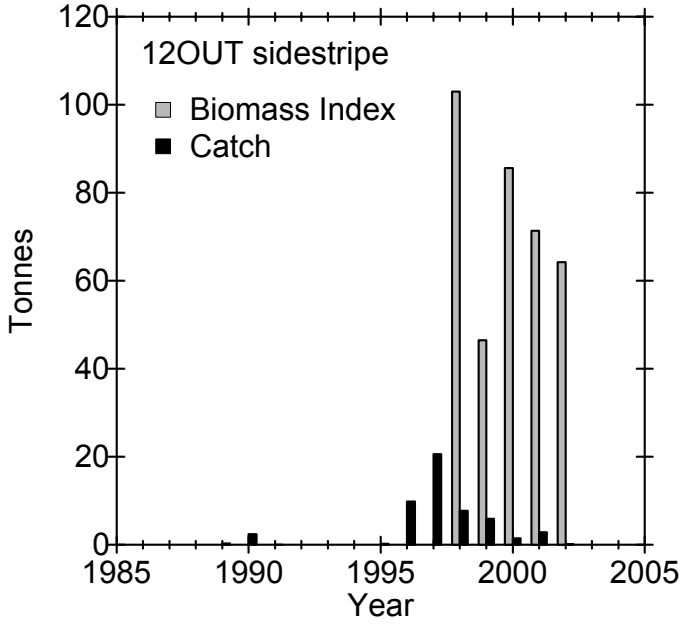

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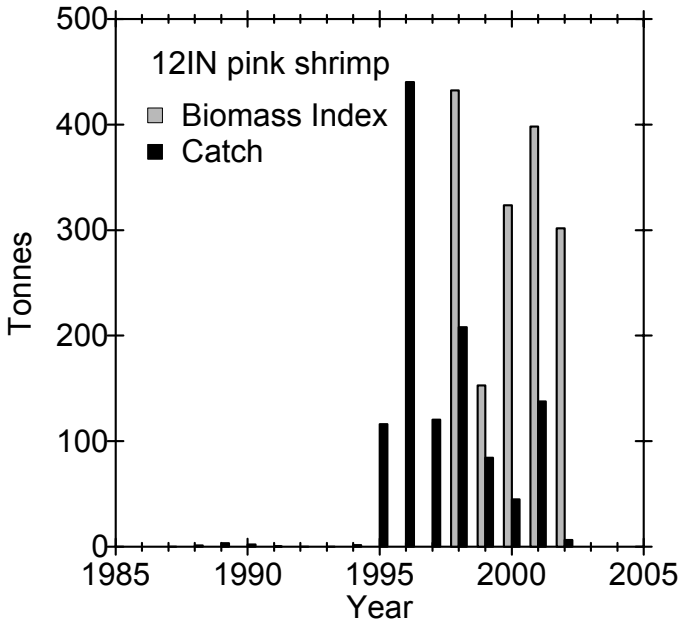

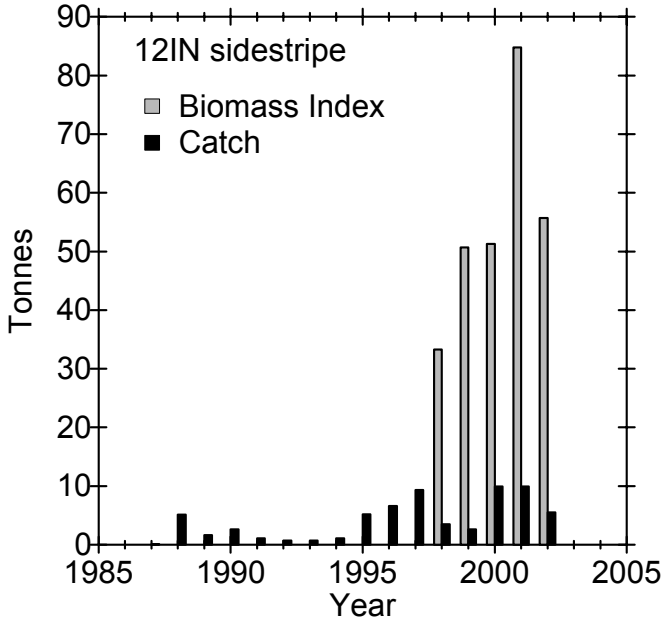

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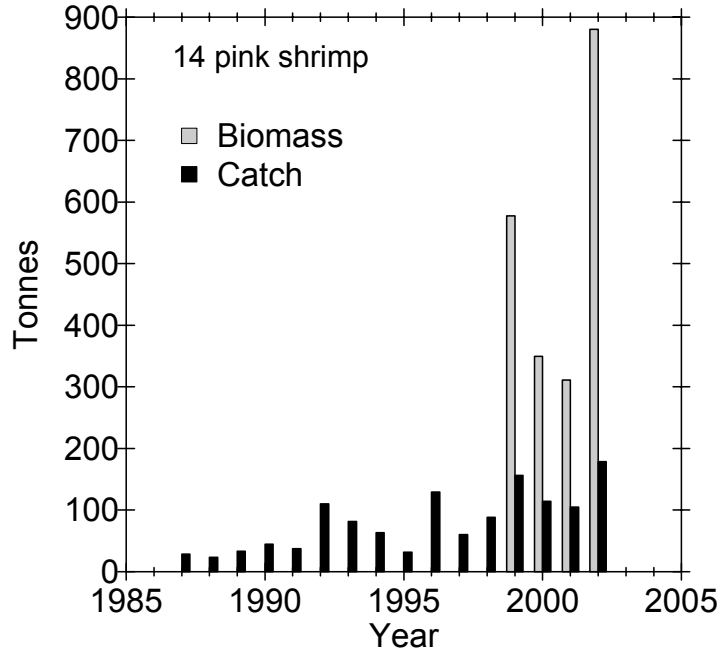

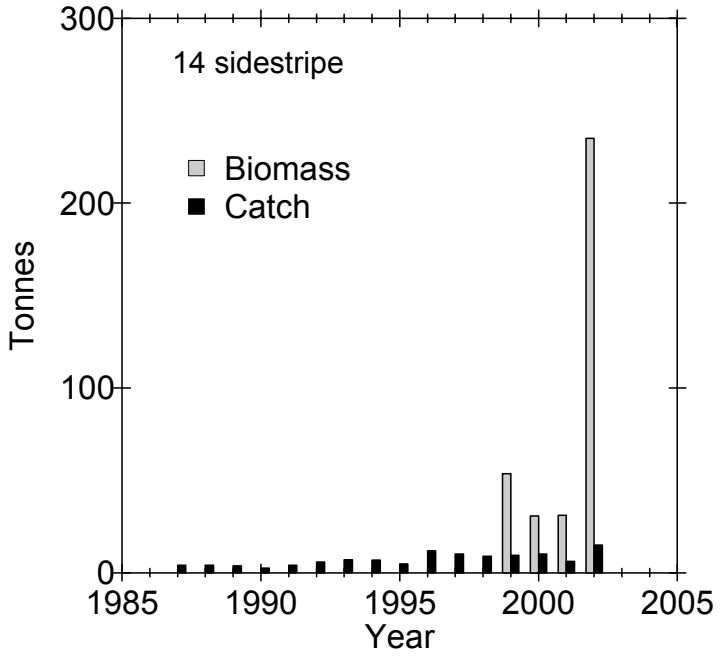

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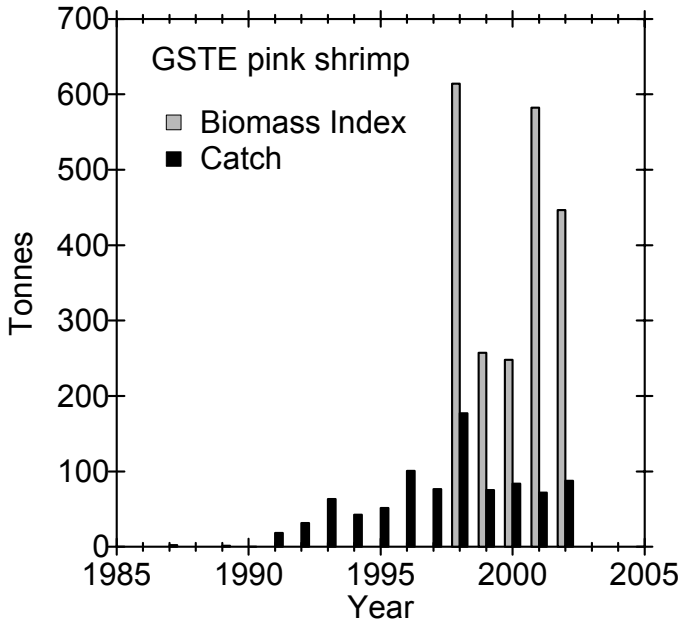

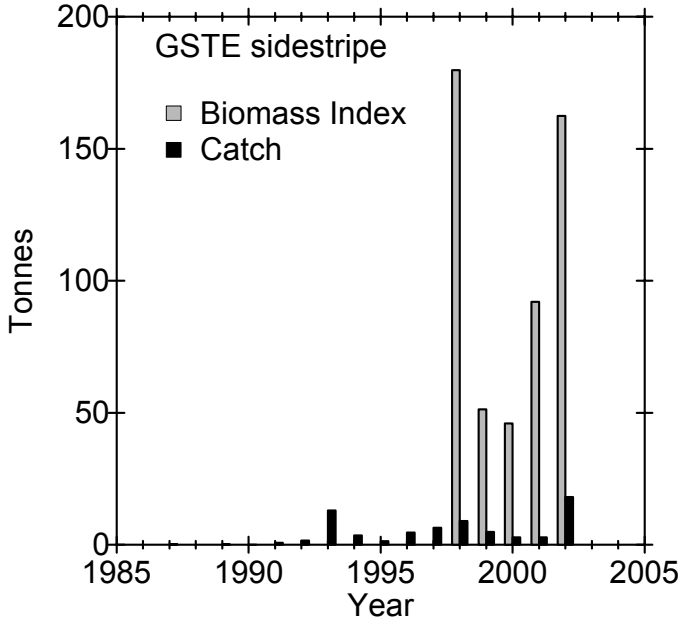

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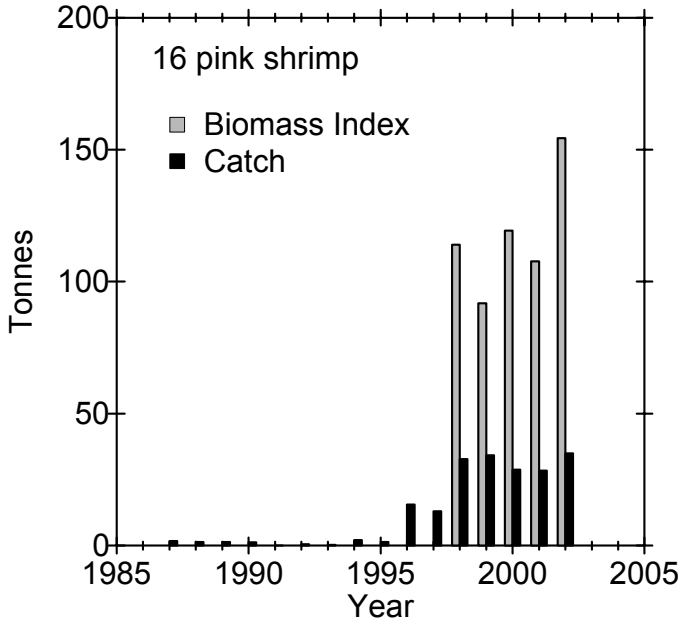

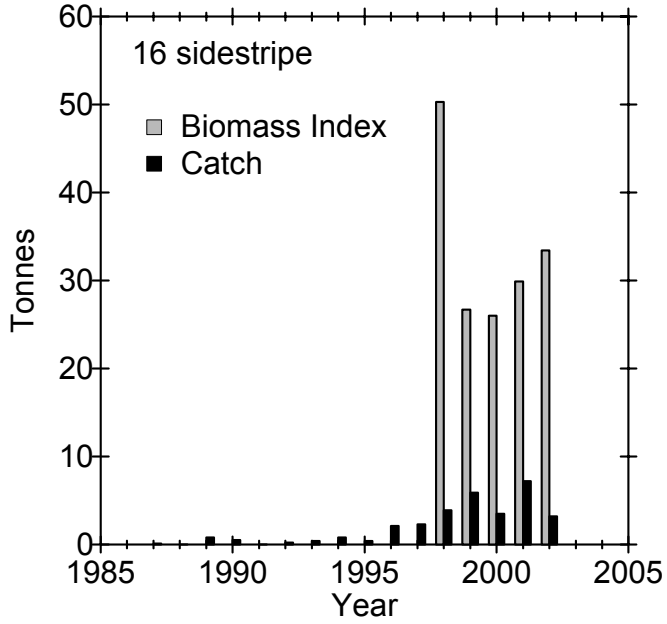

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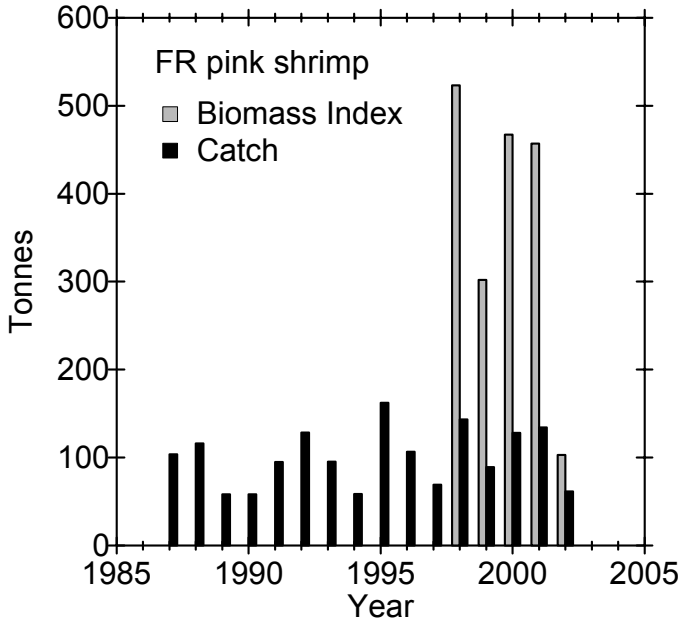

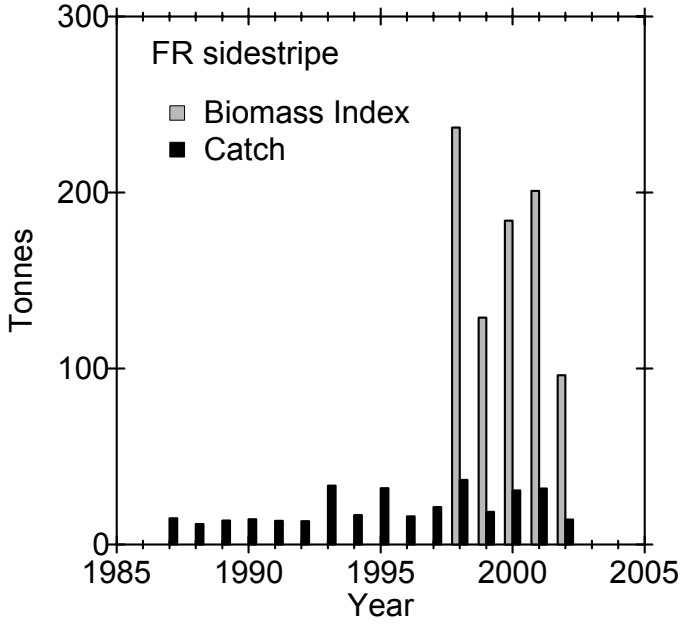

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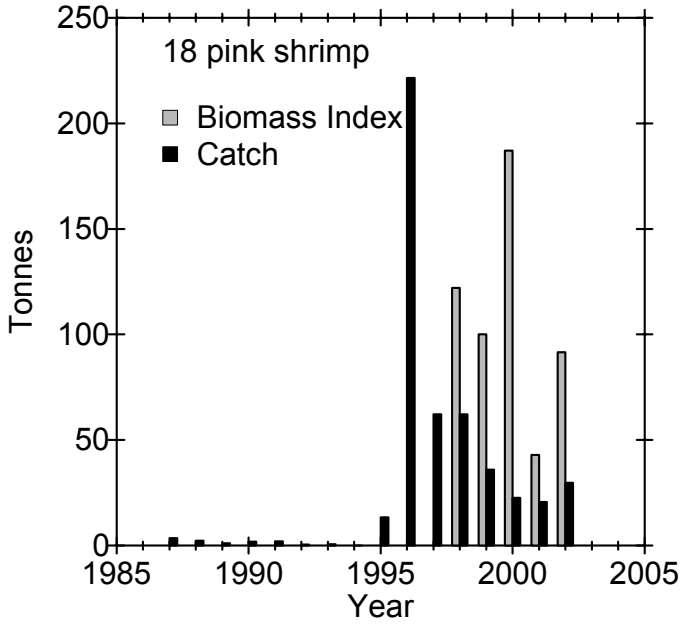

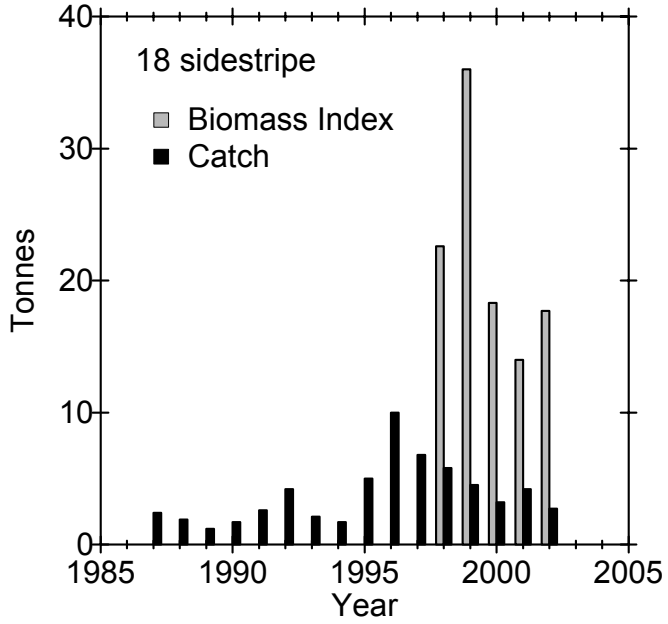

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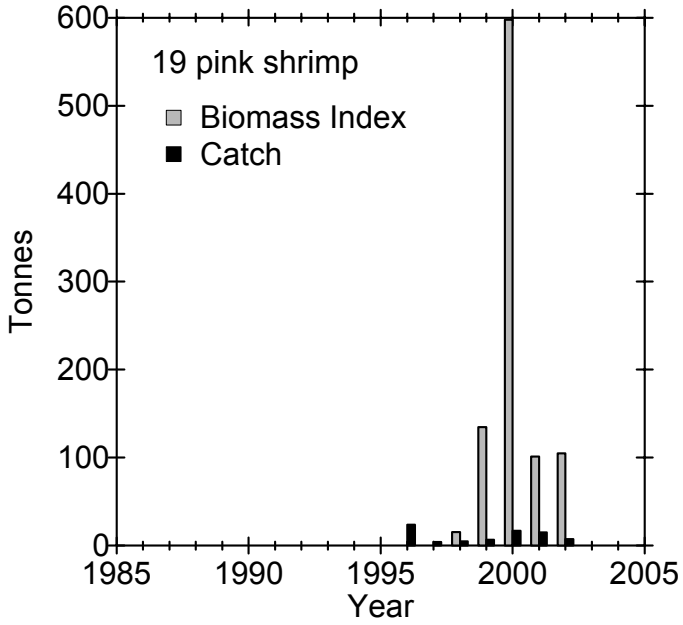

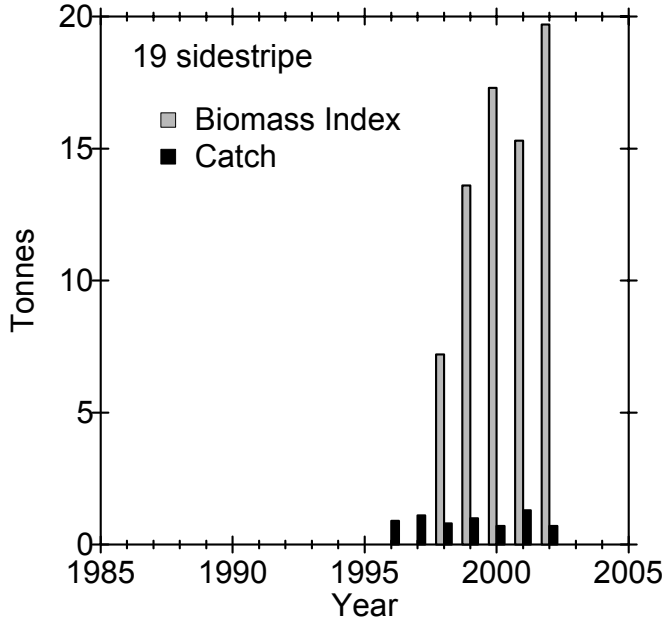

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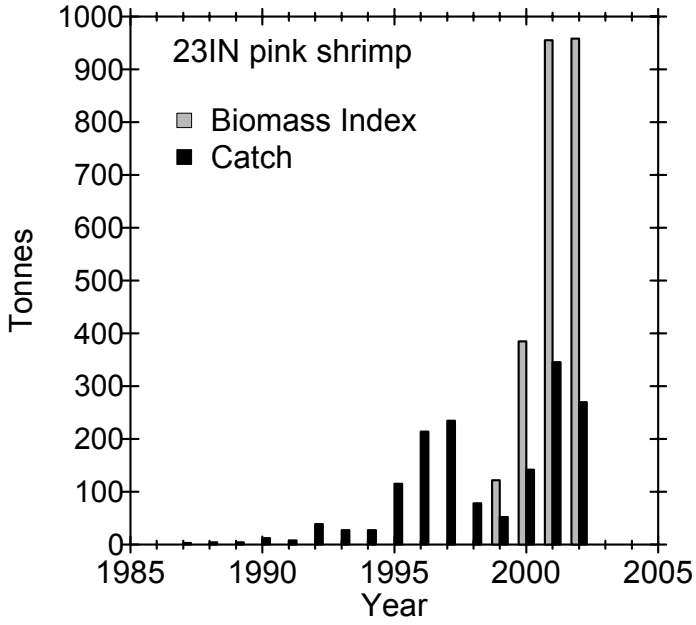

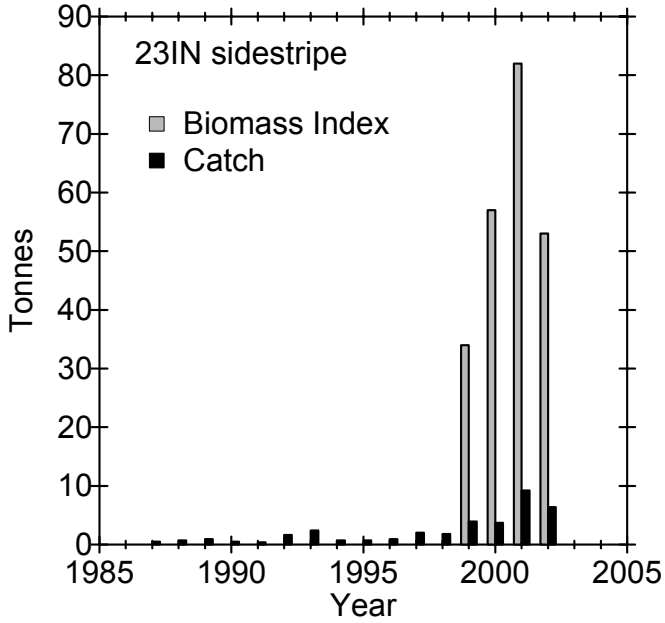

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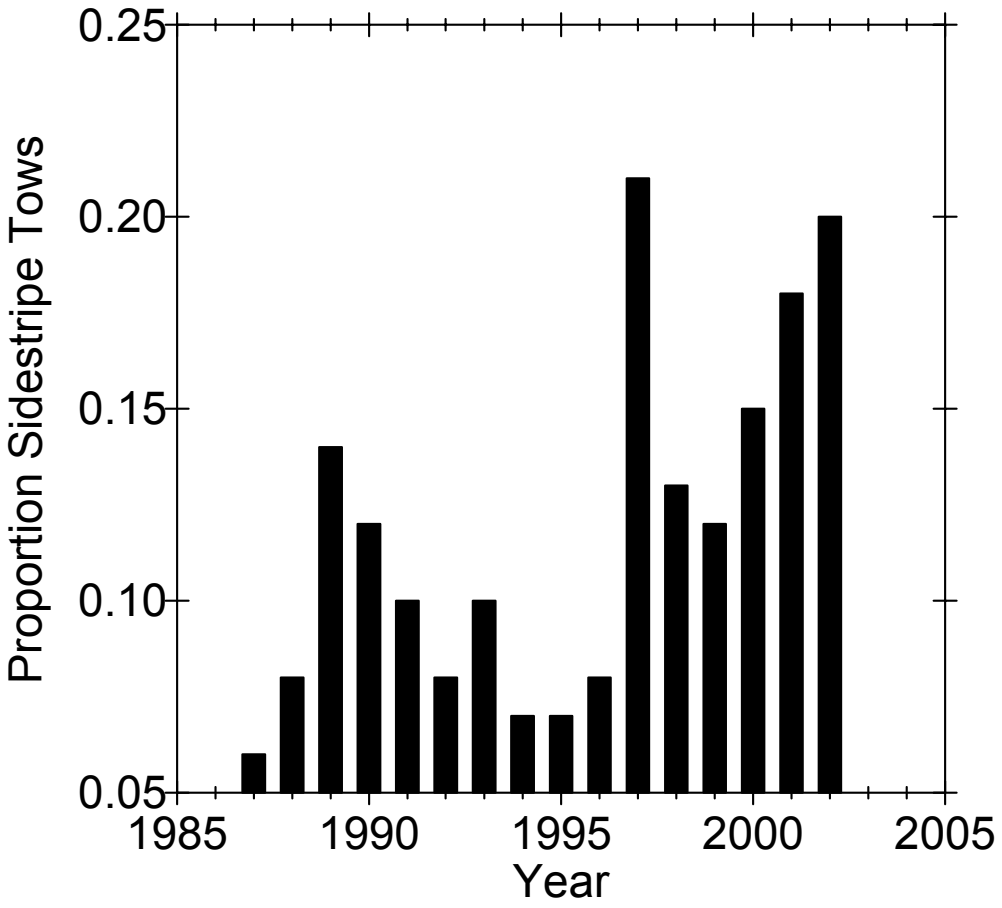

Figure 5. Proportion, by year, of the annual coast wide shrimp tows targeting sidestripe shrimp.

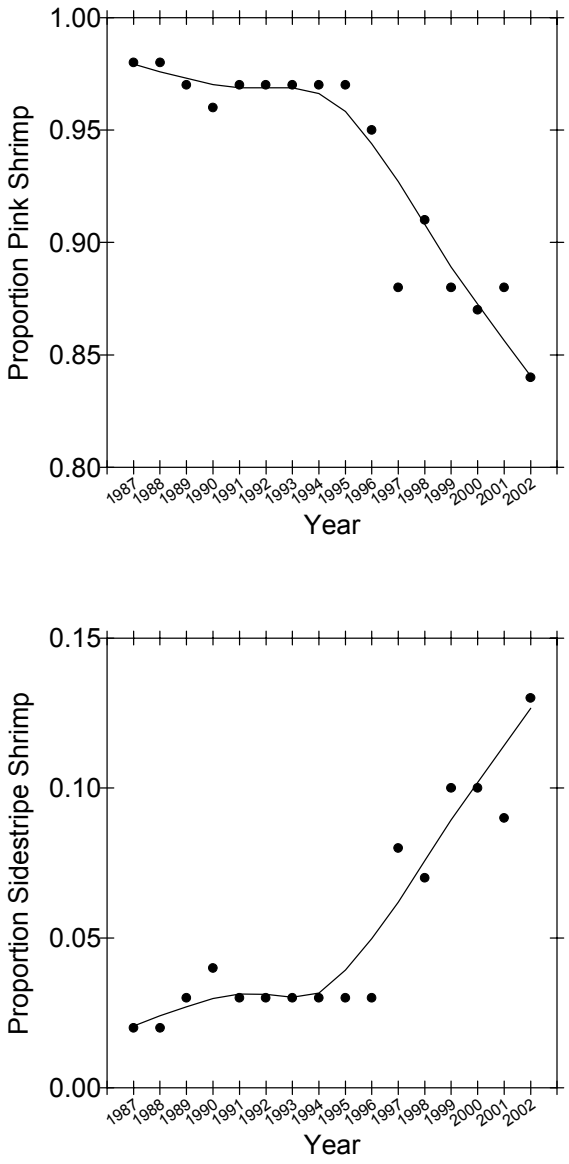

Figure 6. Proportion of pink shrimp (top frame) and proportion of sidestripe shrimp (bottom frame) in the annual total shrimp catch. Lowess line fitted to data points.

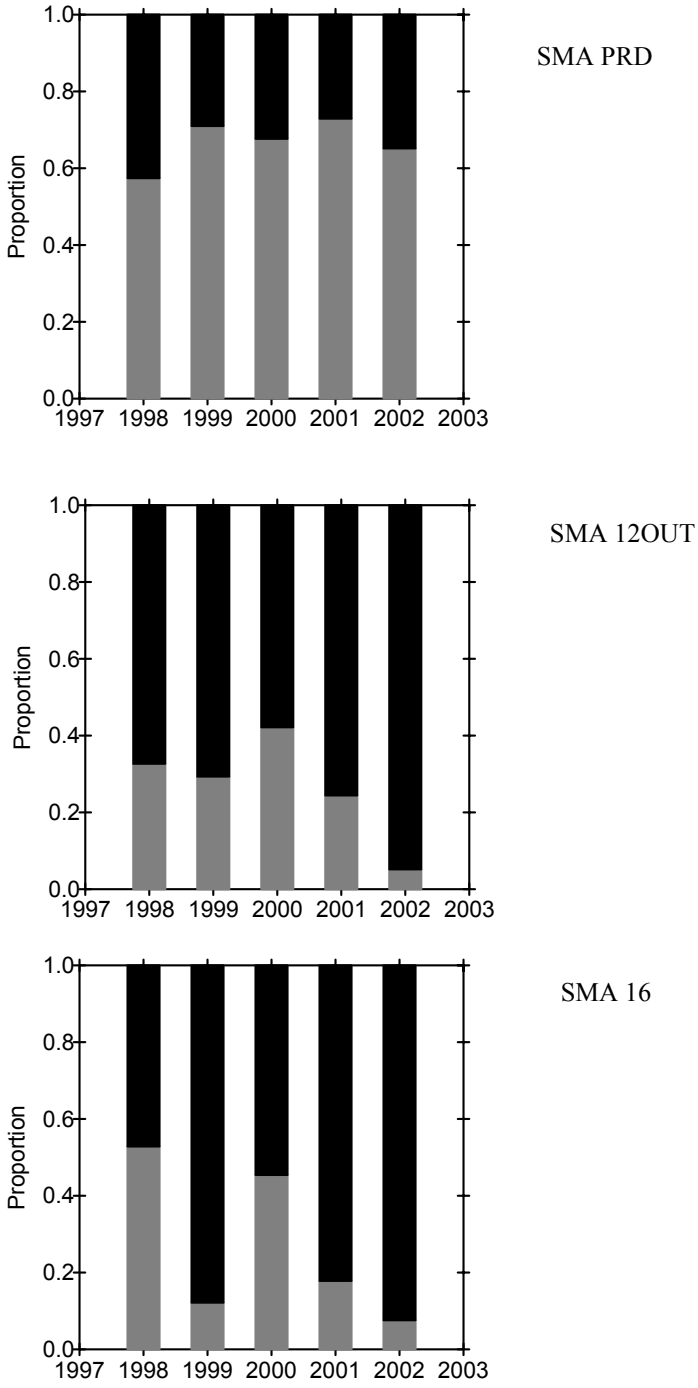

Figure 7. Annual fluctuations in the proportion of *P. borealis* (grey bar) and *P. jordani* (black bar), by SMA, that constitute the total pink shrimp catch.

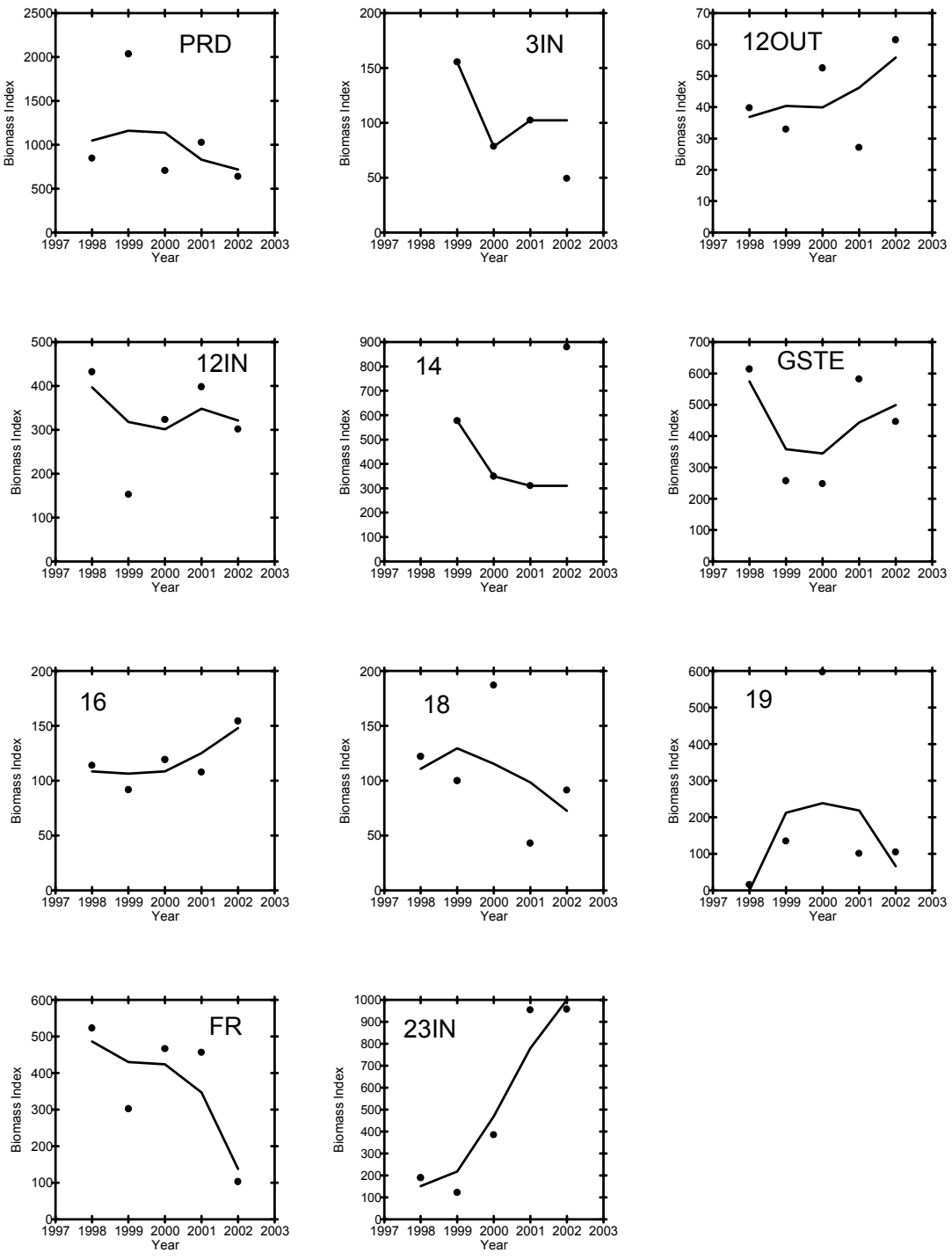

Figure 8a. Trend in pink shrimp biomass, by SMA. Lowess line fitted to data.

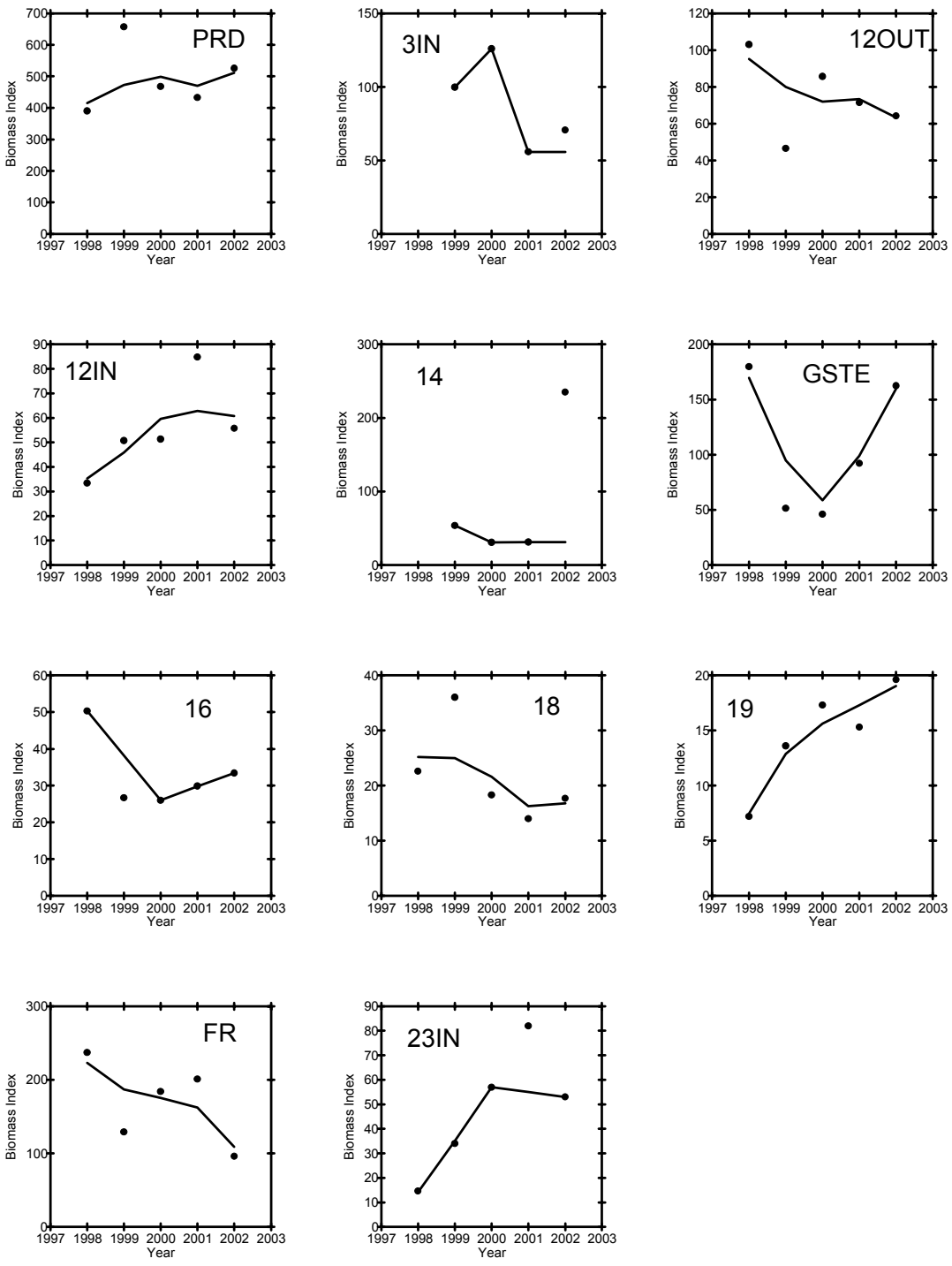

Figure 8b. Trend in sidestripe shrimp biomass, by SMA. Lowess line fitted to data.

Appendix 1. Request for working paper

PSARC INVERTEBRATE SUBCOMMITTEE

Request for Working Paper.

Date Submitted: Feb. 28,2002 (Revised Mar. 7)

Individual or group requesting advice:
(Fisheries Manager/Biologist, Science, SWG, PSARC, Industry, Other stakeholder etc.)
Fisheries Managers, Pacific Coast Shrimpers Association

Proposed PSARC Presentation Date:
November, 2002

Subject of Paper (title if developed):
A summary of industry supported shrimp trawl surveys over the past 5 years, including the results of the recent Fraser River survey-fishery-resurvey.

Stock Assessment Lead Author: Boutillier, Rutherford

Fisheries Management Author/Reviewer: K. West, G. Parker, B. Bornhold, R. Harbo and J. Hepples

Rationale for request:
(What is the issue, what will it address, importance, etc.)
There have several years of collaborative and industry funded surveys since 1996. How have the surveys contributed to the knowledge of the stocks and the development of a stock assessment framework?

The department may have to enter into a collaborative agreement with industry to continue the funding surveys. A progress report and review is appropriate.

Question(s) to be addressed in the Working Paper:
(To be developed by initiator)

1. A brief review of the survey methodology and refinements should be presented (reference to earlier groundbreaking work)? What changes in methodology have occurred over the past 5 years

2. Are surveys able to detect the impacts of fishing, as tested in the Fraser River area, with a survey, a fishery and a resurvey? Has this been studied in other shrimp areas?

3. What areas have had the greatest difference between survey results and historical fishing landings? What areas have shown the greatest fluctuation is estimates of biomass? Surveys of Area 12 stocks have not been at the level of the peak fishery in that area (?). Catch rates were phenomenal in Area 12- were they non-sustainable or do stocks fluctuate widely in this area? Are there areas that are consistent.

4. How has catch and effort data been in areas where the stocks have been extrapolated from surveys in adjacent areas?

5. What is the appropriate time that a survey is valid? Are annual surveys required in all areas? Are there fishery dependant data that may contribute to the stock size estimates in season

6. What biological samples from the fishery are required in support of the surveys?

7. How have fishing practices changes in time, area and species? What information is required to detect and monitor these changes.

Objective of Working Paper:
(To be developed by FM & StAD for internal papers)

To demonstrate the long term benefits of a science-based assessment, rather than using historical average catches at periods of "low levels" of fishing.

Stakeholders Affected:

How Advice May Impact the Development of a Fishing Plan:

Timing *Issues Related to When Advice is Necessary*

Appendix 2. Example of Shrimp Trawl Fishing Log (Harvest Log).

Shrimp Trawl Log - Record By Tow

V.R.N. formerly CFV | Vessel _____ | Skipper _____ | Year 2 0 _ _

Mail to: *Shellfish Data Program, Pacific Biological Station, Nanaimo, BC, V9R 5K6*

Gear description: Check boxes and fill in blanks appropriate to your gear type

Catch Weights: ☐ Pounds or ☐ Kilograms

Depths: ☐ Fathoms or ☐ Metres

TOW Type: ☐ Doors ☐ Post Beam ☐ Sled Beam

NET Type: ☐ Flat ☐ High-lift ☐ Semi-balloon

Footrope Length _____ (ft) | Headrope Length _____ (ft) | Rise of Net _____ (ft)

Selectivity Gear Used: ☐ Separator grate (Rigid BRD) ☐ Soft web excluder (Soft BRD) ☐ Fisheye ☐ Plastic Lattice Escapement panel ☐ Soft Mesh Escapement panel ☐ Other:_____

Average Tow Speed: _____ Knots

	FISHING HAIL NUMBER	TIME SET Month	Day	Hour	TOW Duration (Minutes)	Distance (Na. Mi.)	START LOCATION (In Degrees and Decimal Minutes) Latitude	Longitude	STATISTICAL Area	Sub-area	DEPTH Min	Max	CATCH WEIGHTS Spiny Pinks	Smooth Pink	Flexed Pink	Sidestripe	Humpback (Kings)	Coon-Stripe	Prawns	Pinks not identified	REMARKS (Include any allowable bycatch, eulachons, etc and the weight here)	PBS Code
1																						
2																						
3																						
4																						
5																						
6																						
7																						
8																						
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10																						
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Revised May, 2001

Appendix 3. By-catch sampling report

BY-CATCH SAMPLING TRIP SUMMARY

Date :
Location :
Vessel: information deleted to protect confidentiality
Skipper:
Sampler:

This vessel was targeting on coonstripe shrimp for the live market. Six tows of approximately 20 minutes in duration were made during the day. Catch from each tow was sorted by hand and only the "larger" coonstripe shrimp were retained. All non retained coonstripe shrimp and bycatch species were released overboard. The sorting procedure involved emptying the catch into a large holding box, the box was then filled with water which remained circulating throughout the sorting period. Small quantities of the catch were dipnetted out of the box and placed on a wet sorting table. From the sorting table large coonstripe were placed into totes (dry) and the rest of catch was placed into large water filled garbage cans. Approximately every half hour the sorted coonstripe shrimp were transferred from the totes into yellow lidded baskets and then placed into live tanks aboard the boat, the garbage cans containing the non retained catch were emptied overboard.

Four of the six tows were sampled for bycatch and the data were recorded onto shrimp trawl datasheets. Random samples of coonstripe shrimp were collected from three of the tows and one sample was collected from the sorted coonstripe shrimp retained. All four samples were brought back to the lab and measured for length/frequency analysis.

The major bycatch species was squat lobster and spiny lebbid shrimp which accounted for approximately 24 % and 9 % of the catch respectively (Table 1). A total catch of 240 kg of coonstripe shrimp was estimated from the four tows, of this, 115 kg of coonstripe shrimp was considered marketable and retained live. Total weight of retained coonstripes shrimp for the day from all six tows was approximately 160kg. The mean length of coonstripe shrimp caught in the tows was approximately 19.5 mm whereas the mean length of coonstripe retained for market was 25.2 mm (Fig.1).

Table 1. Summary of predominant species caught. Predominant species is defined as any species where total weight in a tow was greater than or equal to 1kg.

		Total	Coonstripe Catch		Squat	Spiny		
Tow #	Area	Catch (kg)	Total (kg)	Retained (kg)	Lobster (kg)	Lebbid (kg)	Prawn (kg)	Pollock (kg)
1	18-06	100	80	45	10	10	0	0
2	18-06	40	25	15	5	10	0	0
3	19-05	144	80	30	60	1	1	0
4	18-06	76	55	25	10	10	trace	1
Total		360	240	115	85	31	1	1
% of Total Catch			(67%)	(32%)	(24%)	(9%)		

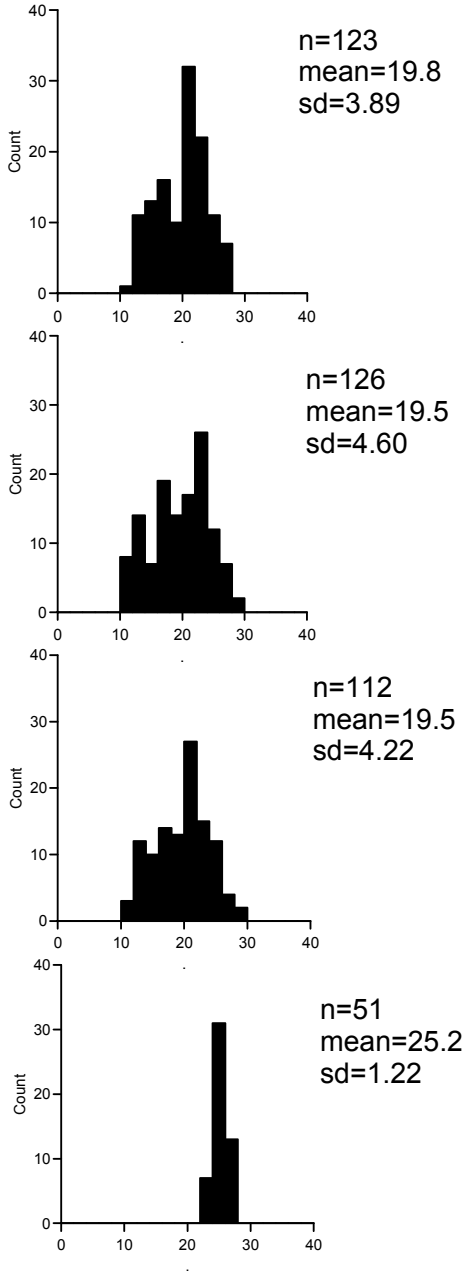

Figure 1. Length distribution of coonstripe shrimp randomly sampled from 3 commercial tows (top 3 frames). Bottom frame is length distribution of coonstripe shrimp retained for commercial market.