



ASSESSMENT OF INSHORE SHRIMP STOCKS ALONG THE COAST OF BRITISH COLUMBIA, 2011

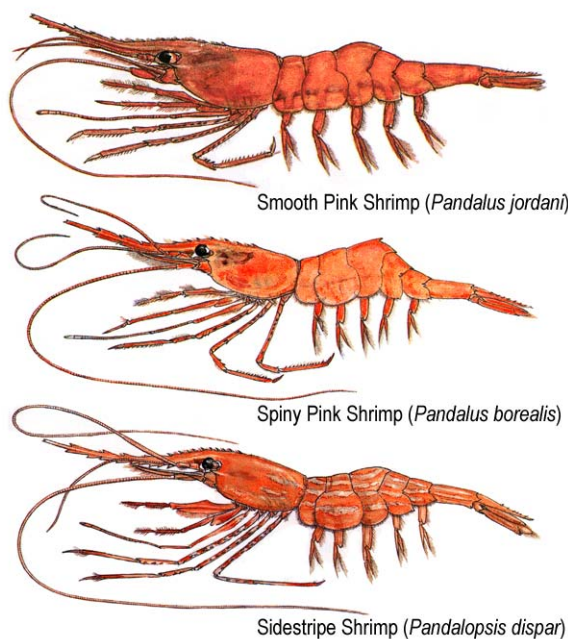


Figure 1. Drawings by A. Denbigh of pink (*Pandalus jordani* and *P. borealis*) and sidestripe (*Pandalopsis dispar*) shrimp.

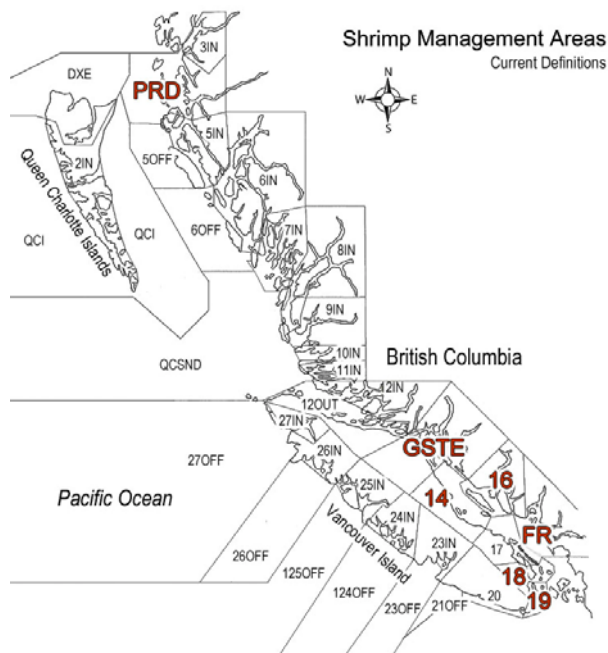


Figure 2. Shrimp management areas (SMA's) along the coast of British Columbia. SMA's highlighted in red font are addressed in this report.

Context:

The inshore shrimp trawl fishery along the coast of British Columbia exploits primarily two species of pink shrimp (*Pandalus jordani* and *P. borealis*) and sidestripe shrimp (*Pandalopsis dispar*) (Fig. 1). Prior to 1996 the fishery was generally open year-round with no catch limitations. Starting in 1995 fishing effort increased sharply with corresponding unprecedented harvest and movement of the fleet into areas that were not historically fished. In response to this increased harvest, significant changes in the management and assessment of shrimp stocks were implemented commencing in 1997. These changes included the development and implementation of an assessment program similar to the one established for West Coast Vancouver Island that utilizes swept-area, fishery-independent trawl surveys to index shrimp biomass (Boutillier et al. 1999; Martel et al. 2000). Shrimp Management Areas (SMA's) and area catch ceilings were also established in 1997 along the entire coast of British Columbia (Fig. 2).

The status of British Columbia inshore shrimp stocks, as indexed through annual surveys, forms the biological basis upon which the Department of Fisheries and Oceans (DFO) Fisheries and Aquaculture Management Branch sets annual area catch ceilings, referred to in this report as total allowable catch (TAC). In addition, in 2009, DFO implemented provisional Precautionary Approach (PA) harvest control rules for shrimp stocks (DFO 2009).

This report is an update to the 2010 Canadian Science Advisory Secretariat Science Advisory Report (DFO 2011) on inshore shrimp stock trends, as indexed through surveys, along with corresponding TAC's from inception of surveys in 1997 to 2011 and commercial catch trends from 1987 to 2010. Commercial catch data are from logbooks and the 2010 data are preliminary. Data for 2011 were not available during the preparation of this report. This report also documents the advice on shrimp stock status in relation to the PA, which was provided to fishery managers and industry in-season.

SUMMARY

- The coast of British Columbia is divided up into 36 Shrimp Management Areas (SMA's).
- Shrimp stock size is indexed through annual swept-area, fishery-independent surveys in selected SMA's.
- In 2011, nine of the fourteen shrimp stocks assessed in this report were in the Healthy zone [*i.e.* above the Upper Stock Reference (USR)]: three stocks, SMA 14 and GSTE pink shrimp and SMA 18 sidestripe shrimp, were between the USR and Limit Reference Point (LRP) and in the Cautious zone; two stocks, SMA 18 and SMA 19 pink shrimp, were below the LRP and in the Critical zone. SMA 12IN shrimp stocks were not assessed in 2011.
- The current assessment concludes that shrimp stocks show high annual variation and that all shrimp stocks were relatively unchanged or decreased from 2010 levels except SMA FR sidestripe which was at a record high.

INTRODUCTION

Species Biology

The biology of shrimp is unique in that they are semelparous and start their life as males and then undergo a sex change in mid-life and become females (Butler 1980). This sex change is known as protandric hermaphroditism and results in the largest size class being comprised of females. Mating occurs in the fall and females carry developing eggs externally on their abdomen from October to March. Eggs hatch in late March to early April. Larvae are planktonic for approximately three months prior to settling on the ocean floor. The maximum age for most of the commercially exploited shrimp species in British Columbia (BC) is four years.

Fishery

The BC shrimp trawl fishery is a limited entry fishery that currently has 243 eligible licences; however there has been a sharp decline in active commercial licences from a peak of 222 in 1996 to 45 in 2011. The shrimp trawl fishery primarily targets pink shrimp (*Pandalus jordani* and *P. borealis*) and sidestripe shrimp (*Pandalopsis dispar*). Two gear types are permitted, otter trawl and beam trawl. Beam trawl is currently the most prevalent gear type in use with 86% of active vessels employing beam trawl gear in 2010.

The shrimp trawl fishery is a multi-species fishery managed to species-specific annual total allowable catch (TAC) by shrimp management area (SMA). For index sites, TAC's are based on the biomass index derived from fishery independent surveys and for non-index sites arbitrary TAC's are used. The implementation of TAC's occurred in 1997 in all SMA's with the exception of the offshore areas that had seasonal openings that were subsequently replaced by TAC's in 2002.

The shrimp trawl fishery is a multi-species fishery where species are mixed both spatially and temporally and, as a result, when the TAC for one species is reached, the entire SMA is closed. Recent low effort in the fishery has also been a contributing factor to not reaching the annual TAC in some of the SMA's.

ASSESSMENT

Status of pink (*Pandalus jordani* and *P. borealis*) and sidestripe (*Pandalopsis dispar*) shrimp stocks along the coast of BC is assessed through fishery-independent surveys designed to index shrimp biomass in selected SMA's. Stock status of shrimp stocks in SMA's 18, 19, FR, 14, 16, GSTE, and PRD (Fig. 2) is discussed and presented in this report along with trends in catch and annual TAC's. Stock status of SMA 12IN shrimp and offshore shrimp stocks is not included in this report because SMA 12IN was not surveyed in 2011 and the reporting of offshore shrimp stock status was beyond the scope of this document. In addition, some of the minor shrimp species, such as coonstripe (*Pandalus danae*) and humpback (*Pandalus hypsinotus*) shrimp, assessed during the inshore surveys, are also not included because they lack an extensive time series to accurately report on stock trend.

Although Precautionary Approach (PA) compliant provisional reference points were only established in 2009 and implemented into the harvest control rules (HCR) in 2010, stock trends from 1997 to 2011 are discussed in relation to the upper stock reference (USR) and limit reference point (LRP) and stock status zones. Estimates of B_{msy} for each shrimp stock were not available so proxies for B_{msy} were calculated. The $\ln(\text{average})$ biomass, using estimated biomass from 1997 to 2007 (which is considered the stable productive period for pink and sidestripe shrimp), was selected as the proxy for B_{msy} (DFO 2009). Provisional reference points for USR and LRP were derived as 80% and 40% B_{msy} , respectively. The Healthy zone is defined as stock size above the USR, Cautious zone between the USR and LRP, and Critical zone below the LRP.

The PA-compliant HCR used to calculate the annual TAC are as follows (DFO 2009):

- 1) For shrimp stocks in the Healthy zone, a 35% harvest rate is applied to the estimated biomass;
- 2) For shrimp stocks in the Cautious zone, a progressive reduction in harvest rate is applied to the estimated biomass where harvest rate = $35\% * ((\text{Biomass} - 40\% B_{msy}) / (80\% B_{msy} - 40\% B_{msy}))$;
- 3) For shrimp stocks in the Critical zone, a harvest rate of 0% is applied to the estimated biomass.

SMA's 18 and 19

SMA 18 and 19 were assessed and managed as two distinct SMA's from 1998 to 2006. Commencing in 2007, SMA's 18 and 19 were combined for management purposes, but the areas continue to be assessed separately.

The SMA 18 pink shrimp biomass index has been variable (Fig. 3A). A record high biomass was observed in 2008 followed by a steep decline in 2009, placing the pink shrimp stock in the Cautious zone, and a subsequent decline in 2010 where it fell in the Critical zone. The 2011 pink shrimp biomass index rebounded slightly, but is still below the LRP and in the Critical zone.

The sidestripe shrimp biomass index in SMA 18 has also been variable, reaching a record high in 2006 (Fig. 3B). Since 2006, a decreasing biomass trend has been observed and the 2011 sidestripe shrimp biomass index remains relatively unchanged from the 2010 level and is below the USR and in the Cautious zone.

The SMA 19 pink shrimp biomass index has been at low levels from 2006 to 2011, relative to the 1999 to 2002 period (Fig. 4A). The 2011 pink shrimp biomass index increased slightly from 2010 levels; however it is just below the LRP and remains in the Critical zone.

The sidestripe shrimp biomass index in SMA 19 has been at low levels from 2007 to 2011 relative to the 1999 to 2002 period, but has been on an increasing trend since 2009 (Fig. 4B). The 2011 sidestripe shrimp biomass index increased from the 2010 level and is in the Healthy zone.

Overall, the 2011 pink shrimp stocks in SMA's 18 and 19 increased from 2010 levels, but are still both below the LRP and in the Critical zone as defined by the PA. The 2011 sidestripe shrimp stocks in SMA's 18 and 19 also increased slightly from 2010 levels, with SMA 18 sidestripes between the USR and LRP and in the Cautious zone but with SMA 19 sidestripe shrimp stocks above the USR and in the Healthy zone. As a result of the 2011 status of these stocks, there was no direct harvest of pink or sidestripe shrimp in these management areas for the 2011/12 shrimp management year.

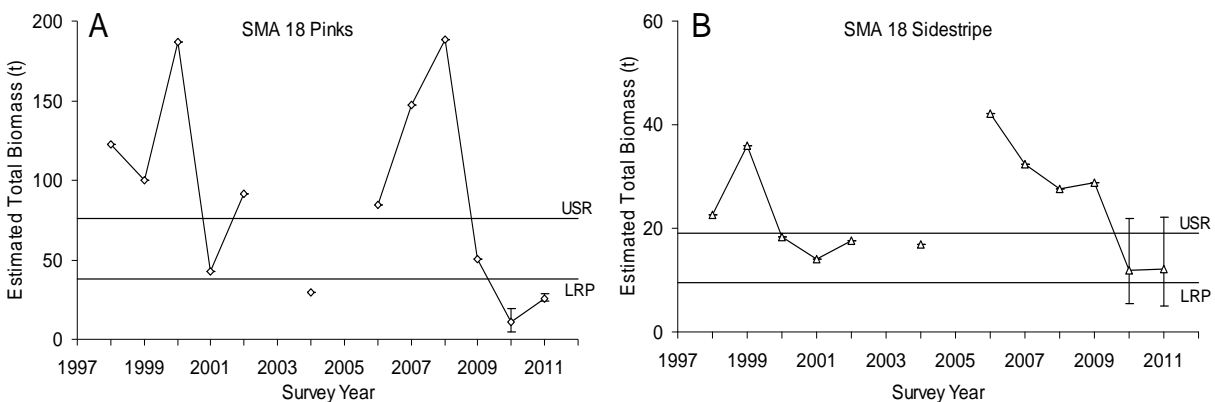


Figure 3. Trends in pink shrimp (A) and sidestripe shrimp (B) biomass in SMA 18, 1998-2011. Error bars represent 95% confidence intervals (CI) for pink and sidestripe shrimp biomass and are only available since 2010 when modifications to the data analysis were made to allow for calculation of CI's.

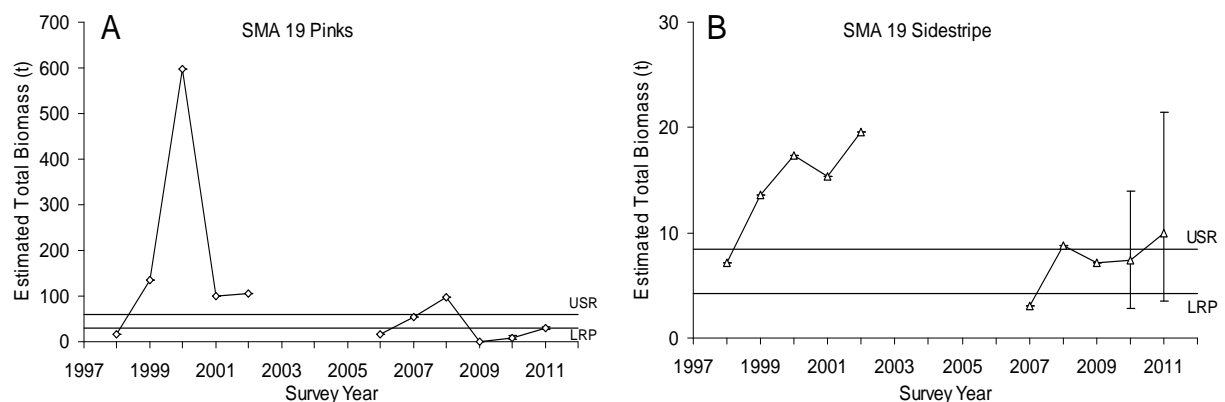


Figure 4. Trends in pink shrimp (A) and sidestripe shrimp (B) biomass in SMA 19, 1998-2011. Error bars represent 95% confidence intervals (CI) for pink and sidestripe shrimp biomass and are only available since 2010 when modifications to the data analysis were made to allow for calculation of CI's.

As noted earlier, SMA's 18 and 19 were managed as two distinct SMA's from 1998 to 2006. During this period TAC's were reached for at least one of the species in both SMA 18 and SMA 19 in all years. These two areas were then combined commencing in 2007. For this report, we

present the combined landings from the two areas but only report annual TAC's commencing in 2007. The catch ceiling for sidestripe shrimp was reached in 2007 and 2008 (Fig. 5C). TAC's were not reached in 2009 and a catch ceiling of zero was assigned for pink and sidestripe shrimp in 2010 (Fig. 5B, C).

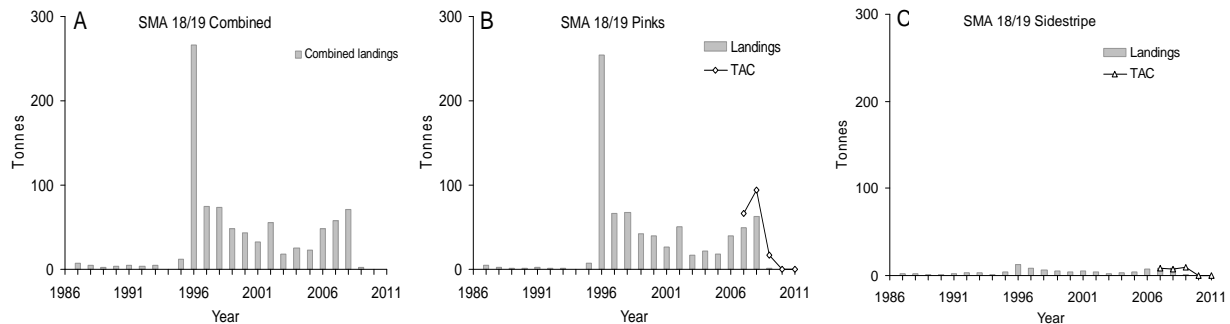


Figure 5. Annual total catch of pink and sidestripe shrimp combined (A), pink shrimp only (B), sidestripe shrimp only (C) and respective TAC's for SMA 18 and 19 combined.

SMA FR

The SMA FR pink shrimp biomass index has been variable (Fig. 6A). Biomass was relatively high from 1998 to 2001, followed by a period of low biomass from 2002 to 2005, which was between the USR and LRP and in the Cautious zone. The 2006 and 2007 biomass index was at the USR and this was followed by an increasing trend to 2009. Subsequently, a decline in pink shrimp biomass was observed in 2010 and 2011, but the stock remains above the USR and in the Healthy zone.

The sidestripe shrimp biomass index was relatively stable from 1998 to 2007 and fluctuated around the USR (Fig. 6B). A steady, increasing trend has been observed from 2007 to 2011 and the stock is well above the USR and in the Healthy zone.

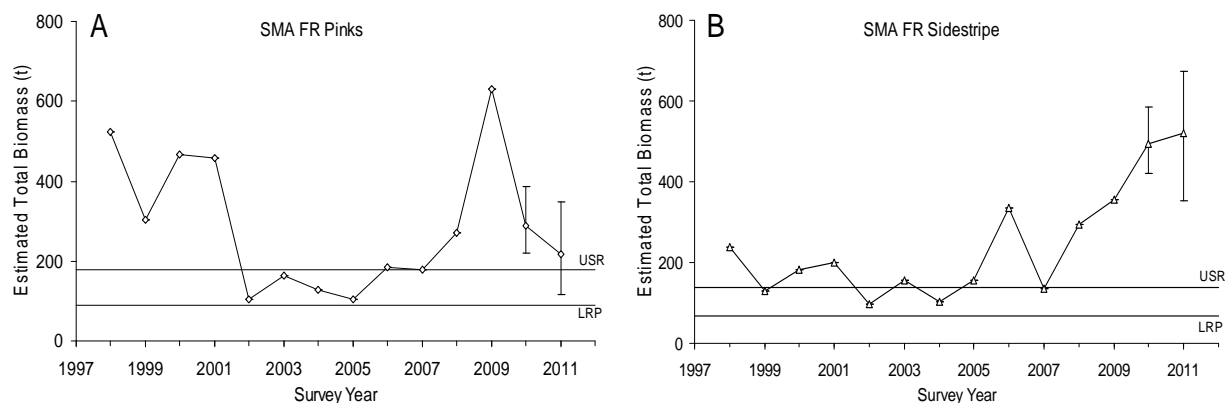


Figure 6. Trends in pink shrimp (A) and sidestripe shrimp (B) biomass in SMA FR, 1998-2011. Error bars represent 95% confidence intervals (CI) for pink and sidestripe shrimp biomass and are only available since 2010 when modifications to the data analysis were made to allow for calculation of CI's.

Annual TAC's, based on survey results, have been in place for SMA FR since 1998; however, from 1998 to 2002 a combined catch ceiling for pinks and sidestripe shrimp was used. Commencing in 2003, the combined catch ceiling for pink and sidestripe shrimp was separated. From 1998 to 2002, the combined period, TAC's were reached in every year except for 1998 (Fig. 7A). From 2003 to 2008 TAC's were reached for pink shrimp in every year and for

sidestripe shrimp in 2005 only (Fig. 7B, C). TAC's were not reached in 2009 due to high biomass, however the pink shrimp catch ceiling was reached in 2010.

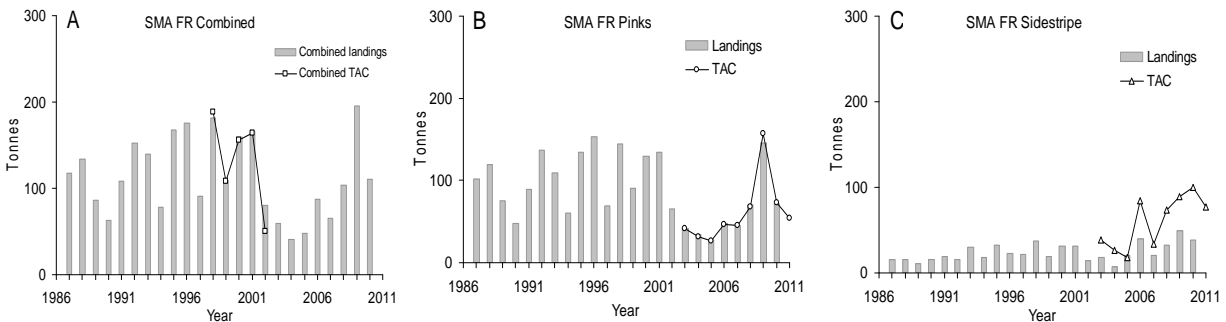


Figure 7. Annual total catch of pink and sidestripe shrimp combined (A), pink shrimp only (B), sidestripe shrimp only (C) and respective TAC's for SMA FR. Note: Commercial catch data for 2010 are preliminary.

SMA 14

The SMA 14 pink shrimp biomass index has been variable with the index dropping below the USR in four of 13 years, with one of those years (2005) below the LRP (Fig. 8A). The pink shrimp biomass index has been steadily declining since 2009 and in 2011 it was just above the LRP and in the Cautious zone.

The sidestripe shrimp biomass index was below the USR and in the Cautious zone from 1999 to 2001 (Fig. 8B). The sidestripe shrimp biomass index has remained above the USR in all subsequent years since 2001, except for 2005. The decline in sidestripe shrimp biomass in 2011 breaks a continuous increasing trend observed since 2008, but it still remains in the Healthy zone.

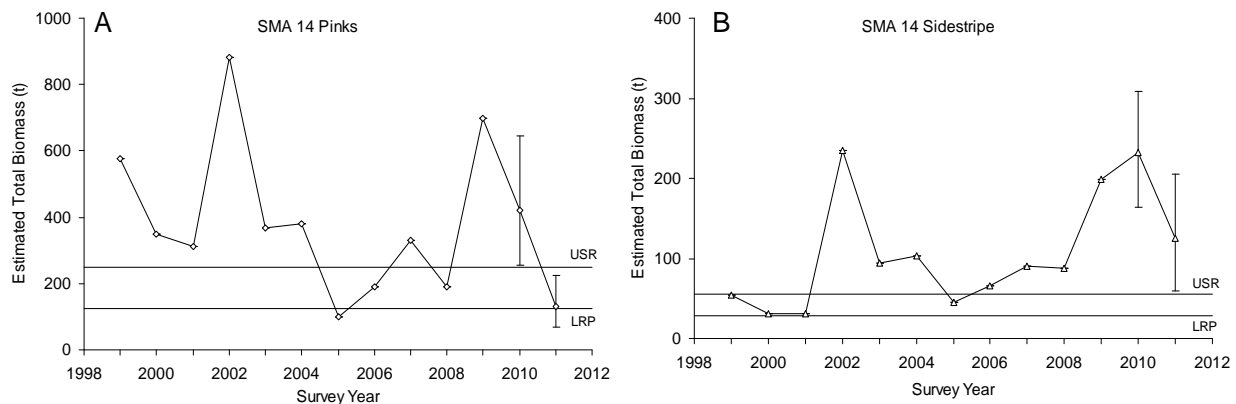


Figure 8. Trends in pink shrimp (A) and sidestripe shrimp (B) biomass in SMA 14, 1999-2011. Error bars represent 95% confidence intervals (CI) for pink and sidestripe shrimp biomass and are only available since 2010 when modifications to the data analysis were made to allow for calculation of CI's.

Annual TAC's, based on survey results, have been in place for SMA 14 since 1999; however, from 1999 to 2002 a combined catch ceiling for pink and sidestripe shrimp was used. Commencing in 2003, the combined catch ceiling for pink and sidestripe shrimp was separated. From 1999 to 2002, the combined period, TAC's were reached in 2000 and 2001 (Fig. 9A). From 2003 to 2010 TAC's were not reached for sidestripe shrimp but were reached for pink shrimp in 2005 and 2006 (Fig. 9B, C).

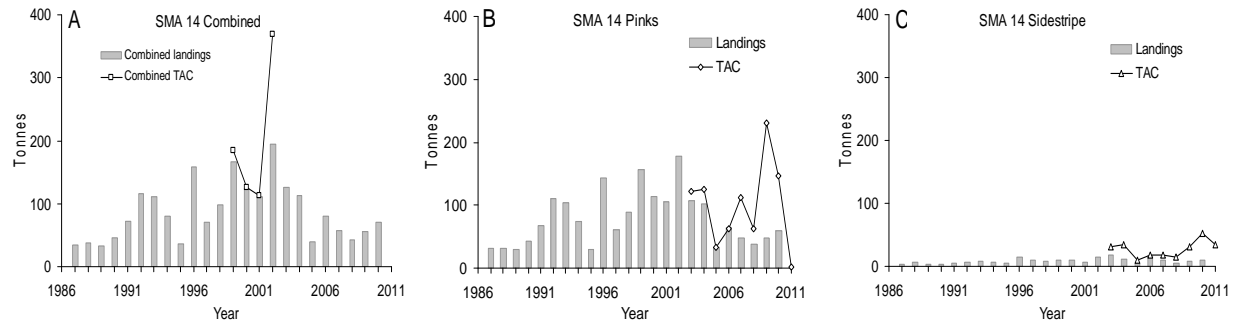


Figure 9. Annual total catch of pink and sidestripe shrimp combined (A), pink shrimp only (B), sidestripe shrimp only (C) and respective TAC's for SMA 14. Note: Commercial catch data for 2010 are preliminary.

SMA 16

The SMA 16 pink shrimp biomass index was relatively stable from 1998 to 2004, falling below the USR in only two years (Fig. 10A). No estimates of pink shrimp biomass are available for 2005 and 2006. The 2007 biomass index was near the USR, but in the Cautious zone. Pink shrimp biomass increased well above the USR in 2008 and 2009. This was followed by a large decrease in 2010 pink shrimp biomass index and a smaller decrease in 2011, but the stock remains slightly above the USR and in the Healthy zone.

The sidestripe shrimp biomass index was fairly stable from 1999 to 2004, falling below the USR in two years, 2003 and 2004 (Fig. 10B). Since 2007, the sidestripe shrimp biomass index has been highly variable but in the Healthy zone except in 2007 where the sidestripe shrimp biomass index fell below the USR and was in the Cautious zone. The 2011 sidestripe biomass index decreased from the 2010 level but remained above the USR and in the Healthy zone.

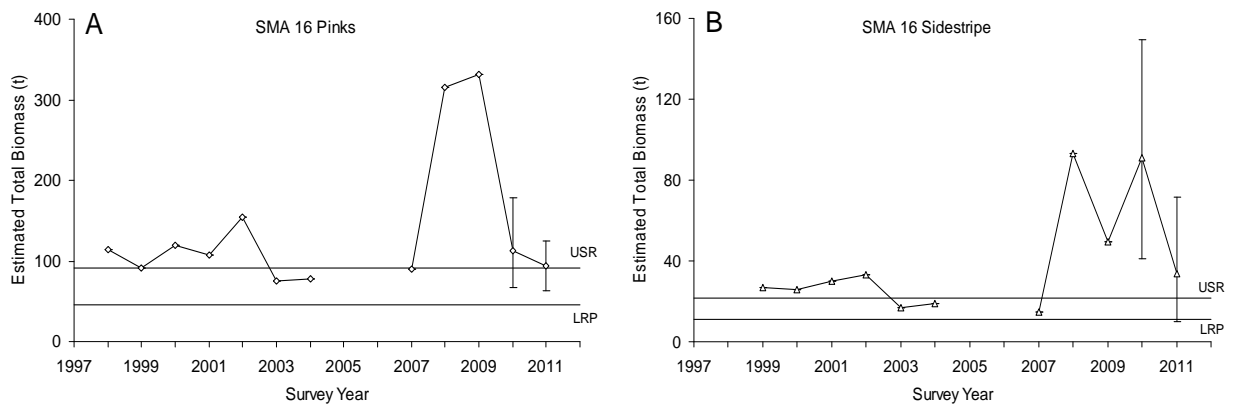


Figure 10. Trends in pink shrimp (A) and sidestripe shrimp (B) biomass in SMA 16, 1998-2011. Error bars represent 95% confidence intervals (CI) for pink and sidestripe shrimp biomass and are only available since 2010 when modifications to the data analysis were made to allow for calculation of CI's.

Annual TAC's, based on survey results, have been in place for SMA 16 since 1998; however, from 1998 to 2002 a combined catch ceiling for pink and sidestripe shrimp was used. Commencing in 2003, the combined catch ceiling for pink and sidestripe shrimp was separated. From 1998 to 2002, the combined period, the catch ceiling was reached in only one year (1999) (Fig. 11A). From 2003 to 2010 TAC's were reached for pink shrimp in 2005 and 2006 and for sidestripe shrimp in 2007 (Fig. 11B, C).

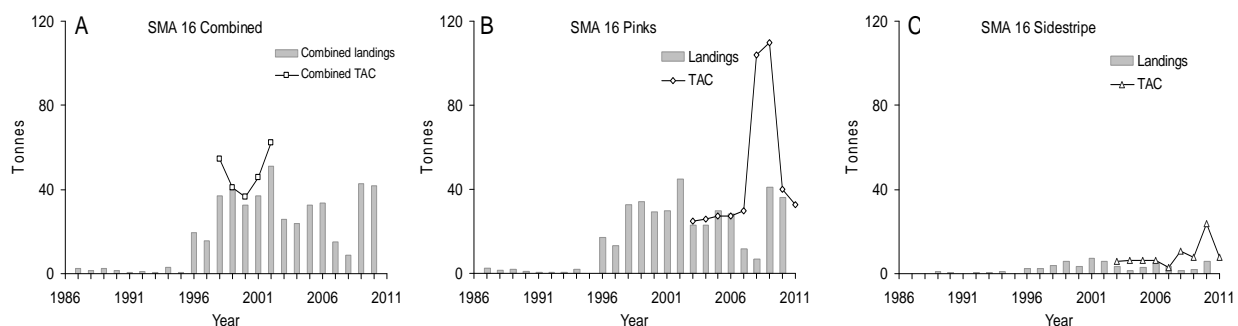


Figure 11. Annual total catch of pink and sidestripe shrimp combined (A), pink shrimp only (B), sidestripe shrimp only (C) and respective TAC's for SMA 16. Note: Commercial catch data for 2010 are preliminary.

SMA GSTE

The SMA GSTE pink shrimp biomass index has been highly variable (Fig. 12A). Pink shrimp biomass has been below the USR in five of the 12 years that estimates are available. The 2011 pink shrimp biomass index was below the USR and in the Cautious zone.

The sidestripe shrimp biomass index was variable between 1998 and 2004 (Fig. 12B). A continual increasing trend in sidestripe shrimp biomass was observed from 2007 to 2010. The 2011 sidestripe biomass index decreased from 2010 levels but remained above the USR and in the Healthy zone.

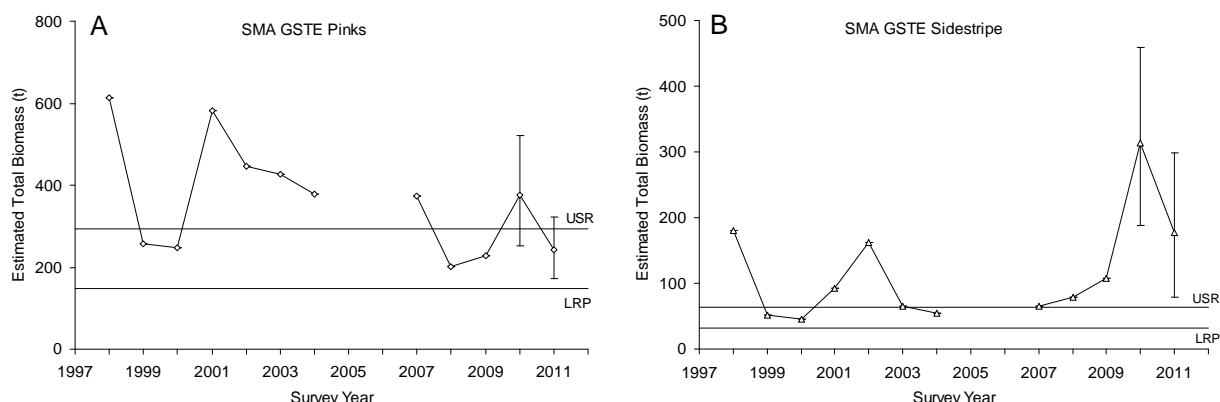


Figure 12. Trends in pink shrimp (A) and sidestripe shrimp (B) biomass in SMA GSTE, 1998-2011. Error bars represent 95% confidence intervals (CI) for pink and sidestripe shrimp biomass and are only available since 2010 when modifications to the data analysis were made to allow for calculation of CI's.

Annual TAC's, based on survey results, have been in place for SMA GSTE since 1998; however, from 1998 to 2001 a combined catch ceiling for pink and sidestripe shrimp was used. Commencing in 2002, the catch ceiling for pink and sidestripe shrimp was separated. From 1998 to 2002, the combined period, TAC's were reached in 1999 and 2001 (Fig. 13A). From 2002 to 2010 TAC's were not reached, except for pink shrimp in 2004 (Fig. 13B, C).

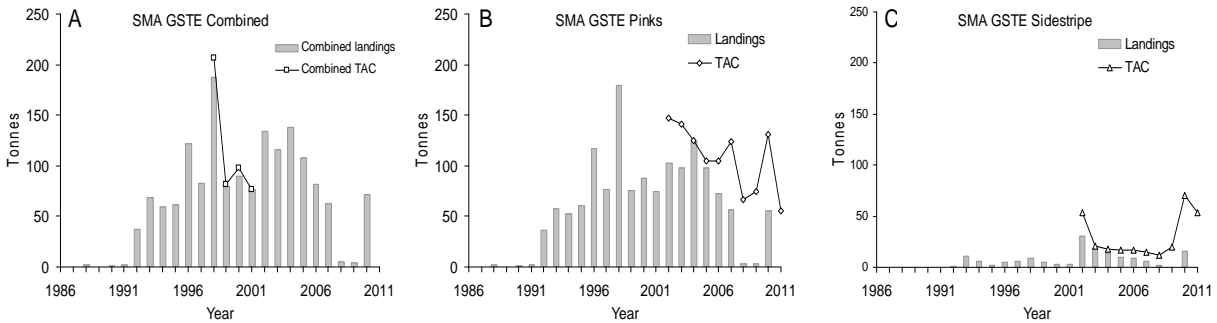


Figure 13. Annual total catch of pink and sidestripe shrimp combined (A), pink shrimp only (B), sidestripe shrimp only (C) and respective TAC's for SMA GSTE. Note: Commercial catch data for 2010 are preliminary.

SMA PRD

The SMA PRD pink shrimp biomass index was variable between 1998 and 2004 and fluctuated above and below the USR (Fig. 14A). From 2005 to 2011 the stock has remained above the USR and in the Healthy zone. The 2011 pink shrimp biomass index increased slightly from the 2010 level.

The sidestripe shrimp biomass index was relatively stable from 1998 to 2004, falling below the USR in only two years (Fig. 14B). A general increasing trend has been observed from 2005 to 2010, but was broken in 2011 with a decrease in sidestripe biomass. The 2011 sidestripe biomass index is still the second highest on record and is well above the USR and in the Healthy zone.

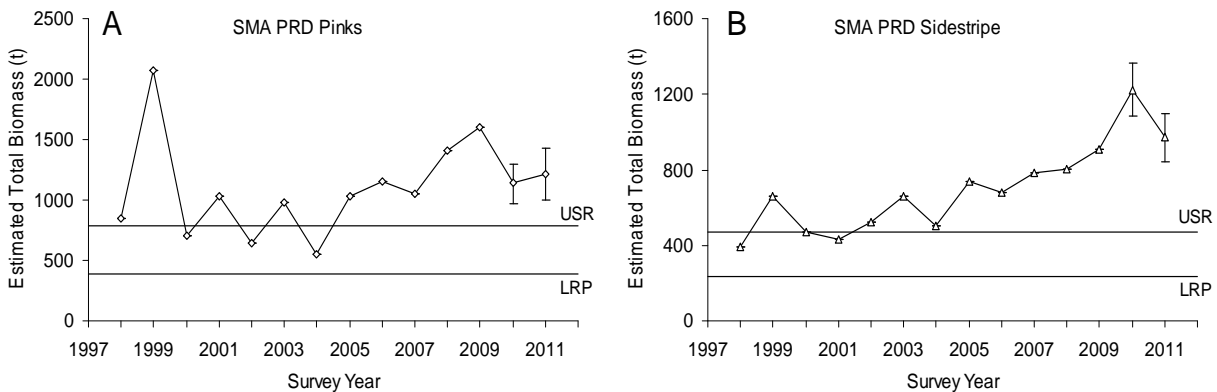


Figure 14. Trends in pink shrimp (A) and sidestripe shrimp (B) biomass in SMA PRD, 1998-2011. Error bars represent 95% confidence intervals (CI) for pink and sidestripe shrimp biomass and are only available since 2010 when modifications to the data analysis were made to allow for calculation of CI's.

Annual TAC's, based on survey results, have been in place since 1998 for SMA PRD but these have never been reached (Fig. 15B, C).

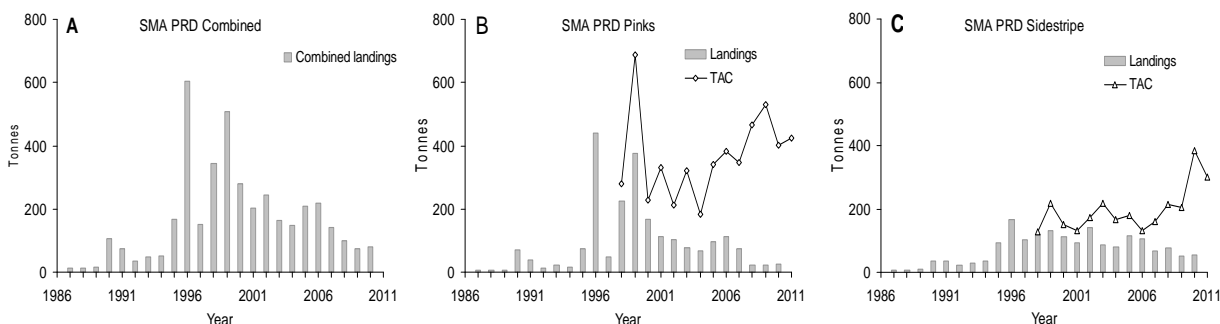


Figure 15. Annual total catch of pink and sideshripe shrimp combined (A), pink shrimp only (B), sideshripe shrimp only (C) and respective TAC's for SMA PRD. Note: Commercial catch data for 2010 are preliminary.

Sources Of Uncertainties

The uncertainties in the estimation of pink and sideshripe shrimp biomass are reported as 95% confidence intervals (CI) and provided to resource managers in-season. The 95% CI's for estimated total pink and sideshripe shrimp biomass are only available since 2010 when modifications to the data analysis were made to allow for their calculation. It should be noted that the 95% CI's are quite wide for some of the biomass estimates and often span across the PA reference points.

Another source of uncertainty is the scaling factor to convert the empirically-derived index to an absolute estimate of biomass. Currently a scaling factor of 1 is used where the index is assumed to be an absolute estimate of abundance.

Ecosystem Considerations

The most pressing ecosystem issues concerning the harvest of shrimp and the shrimp trawl fishery are bycatch, benthic impacts and exploitation of forage fish species. A bycatch monitoring program is in place for the shrimp trawl fishery. Estimates of bycatch by tow are available for trips that are observed; however, coverage is very low which precludes the ability to estimate total annual bycatch by the fishery.

The potential impacts of mobile bottom trawl gear on benthic habitat, populations and communities are well documented (DFO 2006). The shrimp trawl fishery off the coast of BC tends to fish in high-energy, soft-bottom environments which are more robust to benthic alteration by trawl gear than complex, high-structure substrate.

Shrimp are identified as a forage fish and are subject to DFO's forage fish policy. The actual role of shrimp as a forage fish in the ecosystem is not quantified.

CONCLUSIONS

Shrimp biomass is highly variable within and between SMA's and among years. In 2011, nine of the fourteen shrimp stocks assessed in this report were in the Healthy zone [*i.e.* above the Upper Stock Reference (USR)]; three stocks, SMA 14 and GSTE pink shrimp and SMA 18 sideshripe shrimp, were between the USR and Limit Reference Point (LRP) and in the Cautious zone; two stocks, SMA 18 and SMA 19 pink shrimp, were below the LRP and in the Critical zone. SMA 12IN shrimp stocks were not assessed in 2011. The current assessment concludes that shrimp stocks show high annual variation and that all stocks were relatively unchanged or decreased from 2010 levels except SMA FR sideshripe which was at a record high.

SOURCES OF INFORMATION

This Science Advisory Report is from the November 29, 2011 Meeting on the Status Update of British Columbia Geoduck Stocks, 2011; and Assessment of Inshore Shrimp Stocks along the Coast of British Columbia, 2011. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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Internet address: www.dfo-mpo.gc.ca/csas-sccs

ISSN 1919-5079 (Print)

ISSN 1919-5087 (Online)

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La version française est disponible à l'adresse ci-dessus.

**CORRECT CITATION FOR THIS PUBLICATION**

DFO. 2012. Assessment of inshore shrimp stocks along the coast of British Columbia, 2011.
DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/085.