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An Assessment of Northern Shrimp and Striped Shrimp in the Eastern Assessment Zone and Western Assessment Zone (Shrimp Fishing Areas 2 and 3)

T.D. Siferd

Fisheries and Oceans Canada
Freshwater Institute
501 University Crescent
Winnipeg, MB R3T 2N6

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Foreword

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

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

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ABSTRACT

The status of the Northern Shrimp (*Pandalus borealis*) and Striped Shrimp (*P. montagui*) resources in the Eastern Assessment Zone is assessed based on the results of fishery-independent surveys conducted by the Northern Shrimp Research Foundation for the years 2006-2012 and commercial catch statistics. Results from individual survey areas within the Eastern Assessment Zone are also provided. Northern Shrimp are assessed to be well within the Healthy Zone of the Precautionary Approach Framework even though biomass has shown a decline over the past three years albeit year to year differences are statistically insignificant. The potential exploitation rate, based on the taking the TAC, is about 14% near the level expected by fishery managers. Striped Shrimp biomass has increased dramatically over one year and is over two times higher than the previous maximum in the time series. This estimate moved Striped Shrimp from the Cautious Zone to well within the Healthy Zone. Great caution must be taken in the use of the 2012 estimate for management purposes. Only future survey results will show whether the estimate is valid.

Reference points for a Precautionary Approach Framework were developed for both Northern Shrimp and Striped Shrimp in the Western Assessment Zone. Reference points were calculated using the same methodology used in other shrimp fishing areas. Since no survey was conducted in the Western Assessment Zone in 2012 data, required to produce the framework, from the previous year's update are included for reference which included surveys conducted in 2007, 2009 and 2011.

Évaluation des stocks de crevette nordique et de crevette ésope dans les zones d'évaluation Est et Ouest (zones de pêche de la crevette 2 et 3)

RÉSUMÉ

Le statut des ressources de crevette nordique (*Pandalus borealis*) et de crevette ésope (*P. montagui*) dans la zone d'évaluation Est est évalué en fonction des résultats de relevés indépendants de la pêche menés par la Northern Shrimp Research Foundation pour les années 2006 à 2012 et des statistiques des prises commerciales. Les résultats de chaque zone de relevé faisant partie de la zone d'évaluation Est sont également fournis. Selon l'évaluation, la crevette nordique se trouve bien à l'intérieur de la zone saine du Cadre de l'approche de précaution, même si sa biomasse a présenté un déclin au cours des trois dernières années; les différences d'une année à l'autre ne sont pas significatives d'un point de vue statistique. Le taux d'exploitation potentiel, basé sur la prise du total autorisé des captures (TAC), montre environ 14 % de différence avec le niveau attendu par les gestionnaires de la pêche. La biomasse de la crevette ésope a connu une augmentation fulgurante dans l'espace d'une année et est plus de deux fois supérieure au maximum précédent dans la série chronologique. Cette estimation fait passer la crevette ésope de la zone de prudence à une position bien à l'intérieur de la zone saine. Il faut faire preuve de beaucoup de prudence en utilisant les estimations de 2012 à des fins de gestion. Seuls les résultats des futurs relevés indiqueront si ces estimations sont valides.

Des points de référence selon le Cadre de l'approche de précaution ont été créés pour la crevette nordique et la crevette ésope dans la zone d'évaluation Ouest. Ces points de référence ont été calculés en utilisant la même méthode que celle des autres zones de pêche de la crevette. Puisqu'aucun relevé n'a été effectué dans la zone d'évaluation Ouest en 2012, les données nécessaires pour produire le cadre à partir des données de la mise à jour de l'an dernier ont été incluses à titre de référence (relevés effectués en 2007, 2009 et 2011).

INTRODUCTION

Two surveys are conducted to assess the shrimp populations within Fisheries and Oceans Canada's (DFO) Central and Arctic region. In 2003, the 17 license holders of the offshore shrimp industry formed the Northern Shrimp Research Foundation (NSRF). In 2005, the NSRF in partnership with DFO began an annual survey based on the boundaries of North Atlantic Fisheries Organization (NAFO) Divisions 0B and 2G. The area of 0B roughly equates to Shrimp Fishing Area (SFA) 2 and 2G to SFA 4. In order to ensure the main historical fishing areas were surveyed, in 2006, the 0B survey was expanded and split into two survey areas called SFA 2 Exploratory (SFA2EX) and Resolution Island (RISA) Survey Areas (Fig. 1). For resource assessment purposes these two survey areas were combined at the 2011 Zonal Assessment Process (ZAP) and designated as the Eastern Assessment Zone (EAZ) (Fig. 2). In 2007, DFO expanded its multi-species assessment survey series to include SFA 3 west of 66°W and repeated biennial surveys of this area in 2009 and 2011 (Fig. 1). The SFA 3 survey area was designated as the Western Assessment Zone (WAZ) at the 2011 ZAP (Fig. 2).

This document presents the results of research surveys conducted in the EAZ and WAZ through the 2012 survey. Fisheries data and fisheries-independent research survey results are the basis of the assessment of Northern and Striped Shrimps in the EAZ and WAZ. The assessment follows the framework developed for SFA4-6 (DFO 2007) where possible.

MATERIALS AND METHODS

SURVEY DESIGN AND PRACTICES

Three survey areas are located within the bounds of the EAZ and WAZ (Fig. 2). Two separate research surveys are conducted to sample the three survey areas. Surveys of the SFA2EX and the RISA survey areas (Fig. 1) are conducted by the NSRF. DFO surveys SFA 3 (Fig. 1) west of the NSRF survey area. The NSRF and DFO surveys are equivalent in survey design, catch processing and survey analysis, but are sampled with different vessels, trawl gear and time of year as detailed below. Both trawl surveys provide the fishery-independent data required for the assessment of Pandalid shrimp stock status in the EAZ and WAZ (SFA 2 and 3).

SFA2EX and RISA Survey Areas

The first survey in 2005 was designed within the borders of NAFO Div. 0B. In 2006, to better encompass the historical shrimp-fishery footprint and align better with management units, the 0B survey area was expanded westward to 66°W and south 60°30'N, then split into two survey areas designated as SFA2EX and RISA. Both survey areas cover depths between 100 and 750 m divided into contours of 100-200, 200-300, 300-400, 400-500, and 500-750 m. Depth contours are further subdivided into sampling strata.

In 2006, the total area of SFA2EX was 103,331 km^2. In 2009, a small 200-300 m stratum was removed from the survey area because the bottom was found to be untrawlable. At the same time, the shrimp industry implemented a voluntary closed area which overlapped the southern part of the SFA2EX and also removed from the survey design. Consequently the SFA2EX area has been reduced to a total area of 99,117 km^2. RISA had a total area of 28,321 km^2 in 2006. In 2007, experience with untrawlable bottom combined with safety concerns for the ship prompted the removal of the 100-200 m strata from RISA. Grid cells determined to be untrawlable were also removed from the survey design. These combined removals in RISA have reduced its total area to 21,900 km^2 from 2010 onward.

In 2005, Doubleday's (1981) method was used to allocate sampling sites based on the NAFO stratifications. In 2006, the redesign of the survey areas, which extended outside the NAFO boundary, required a revision to the stratification scheme. The new area added to the survey was stratified to and matched with the existing contours. A 3 by 3 km grid was superimposed over an equal-area projection of the stratified survey area. To continue using the Doubleday method, large blocks were formed from nine grid points in a square pattern wherever possible. The actual number of grid points varied depending on the curvature of the stratum border. In 2005 and 2006 in SFA2EX and RISA, the samples are allocated in proportion to stratum area with a two set minimum regardless of stratum size. Starting in 2007 in

SFA2EX, 87 samples are proportionally allocated by stratum area and an additional 34 sets allocated optimally (Cochran 1977) based on the variance observed within strata in the two previous surveys in an effort to control overall confidence intervals of the biomass estimate. Sampling sites were located by first randomly selecting the appropriate number of large blocks as allocated to a stratum, then randomly selecting a single grid point from within each of the selected large blocks. RISA continued to be proportionally allocated.

SFA2EX and RISA surveys are conducted annually in August using the fishing vessel Cape Ballard with a Campelen 1800 shrimp trawl (Walsh et al. 2009). Owned by Ocean Choice International, the Cape Ballard is a 45.9 m (992 GRT) stern trawler. The trawl was spread with Morgere® Polyvalent doors weighing 1400 kg and 4.3 m^2 in area. In 2012, the Cape Ballard was replaced with the Aqviq. Analysis concluded that given the similarity in specification, conversion factors would not be required to continue with a comparable time series (S. Walsh, DFO Emeritus, pers. comm.).

The standard Campelen trawl has 14 inch rubber disk 'rockhopper' ground gear with a single cod end fitted with a 12.7 mm mesh liner. Use of the Campelen trawl in the north resulted in many tear ups of the gear, especially in RISA, so a modified Campelen trawl was developed. Changes to the trawl increased the footgear size to 21 inches, floated the fishing line to reduce the weight of the trawl, increased the length of the toggles and added a polypropylene rope to the lower rib line (Siferd and Legge 2014). Dimensions and mesh sizes in the trawl body were not changed. In 2008, the modified Campelen trawl was used in RISA with no tear ups recorded. The modified Campelen was used in both the SFA2EX and RISA survey areas in 2009 and will continue to be used in future surveys of the two areas.

A 1 m by 1 m juvenile shrimp net made of 12.7 mm mesh (Nilssen et al. 1986; Aschan and Sunnan 1997) was attached to the third belly of the trawl forward of the cod end attachment. Samples collected in the juvenile shrimp net were weighed, in some cases subsampled and the final sample frozen on-board the ship and returned to the lab ashore for processing.

Trawl monitoring has been problematic on the Cape Ballard. Various trawl monitoring systems have been used to observe trawl geometry; Netmind® (2005-2006) was replaced by Scanmar® (2007-2009). The current configuration (2010) used a Marport® MBAR with Marport and Scanmar spread sensors to measure door spread and wing spread. In 2010, a Furuno® trawl eye mounted on the headline was also added to improve the visualization of trawl touchdown and therefore start/end of tows. Prior to 2010, bottom time was measured from depth-time traces recorded with a Seabird® CTD mounted on the headline. In 2010, Marport recordings of the Furuno trawl eye were used to determine the start and end of the tow and thereby bottom time. Sampling was conducted on a 24 hour basis.

The swept area of each tow was determined through the multiplication of speed, bottom time and wing spread. Prior to 2010, speed was determined from the average of five GPS speeds recorded on deck sheets distributed evenly over the 15 minute duration of the tow. In 2010, the average of all speeds from GPS GPRMC strings recorded by the Marport system over the duration of the tow was used. Wing spread was determined either through direct measurement or by conversion from door spread through the formula derived from a comparison of door spread to wing spread over tows where both measures were present. All available wing spread measurements (direct or derived) were averaged over the duration of the tow. Bottom time was determined from depth-time recordings Seabird CTD (2005-2009) or Marport recordings of the Furuno trawl eye (2010 onward).

Water temperature and salinity was recorded with a trawl mounted Seabird 19plus CTD. Bottom temperature was considered the average of all measurements taken between the start and end of the tow while the trawl was on bottom.

SFA3 Survey Area

SFA3 has a total area of 58,279 km^2. The SFA3 survey area covers the depths of 100 to 1,000 m divided into contours of 100-200, 200-300, 300-400, 400-500, 500-750 and 750-1,000 m. The bathymetry of SFA3 is such that natural strata were produced and no further subdivision of the contours was made. The SFA3 is surveyed biennially. Three surveys of the area have been completed to date; 14-25 October 2007, 9-16 October 2009 and 29 September–8 October 2011.

In SFA3, sampling stations within a stratum were allocated in proportion to stratum area but with the requirement of a two set minimum regardless of stratum size. All possible sampling sites within a survey area based on a 3 by 3 km grid overlaying an equal-area projection of the stratified area were assigned to individual strata. A program developed by the Greenland Institute of Natural Resources (GINR) for buffered random sampling (Kingsley et al. 2004) was used to select sampling stations within each stratum of the study area.

The SFA3 survey areas are sampled using the GINR research vessel Paamiut towing a Cosmos® 2000 shrimp trawl. The Paamiut is a 58.9 m (722 GRT) stern. The Cosmos trawl has 21 inch rubber-disk and bobbin 'rockhopper' ground gear. The trawl has twin cod-ends with an inner liner of 20 mm stretched mesh. Injector International® 7.5 m^2 doors weighing 2,800 kg spread the trawl. Standard sampling procedures are to maintain a speed of 2.6 knots for 15 minutes for all tows. However, any tow with a duration greater than or equal to 10 minutes was also considered successful. Sampling was conducted on a 24 hour basis.

The trawl bottom touchdown, i.e., start of tow, was monitored real time with a Furuno® trawl eye mounted on the headline of the trawl. Trawl geometry was monitored through a combination of the trawl eye and Scanmar spread sensors mounted in the doors. In 2009, Marport® spread sensors in stainless-steel protective canisters were mounted at the wing tips to get direct measurements of wing spread. A Marport MBAR records all trawl geometry as well as GPS speed for the determination of swept area.

The swept area of each tow was determined through the multiplication of speed, bottom time and wing spread. Prior to 2008, speed was determined from the average of five GPS speeds recorded on deck sheets distributed evenly over the 15 minute duration of the tow. From 2008 onward, the average of all speeds from GPS GPRMC strings recorded by Marport over the duration of the tow was used. Wing spread was determined either through direct measurement (2010 onward) or by conversion from door spread through the formula derived from Cosmos model tested in a flume tank (Siferd 2010) when direct measurements were not available. All available wing spread measurements (direct or derived) were averaged over the duration of the tow. Bottom time was determined from depth-time recordings from a trawl mounted Starr-Oddi® (2006) or Seabird CTD (2007) or Marport recordings of the Furuno trawl eye (2008 onward).

Water temperatures were measured on each tow of the survey. In 2006, a Starr-Oddi DST-CTD set at a 1 second sampling interval was mounted on the headline and/or the trawl door. Starr-Oddi measurements were inter-calibrated with Seabird CTD during vertical profiling operations. Temperature was corrected to the Seabird equivalent. After 2006, a Seabird 19plus CTD was mounted at the center of the headline. Bottom temperature was considered the average of all measurements taken between the start and end of the tow while the trawl was on bottom.

CATCH PROCESSING

Catch in all survey areas were processed in the same manner. From the catch, a random shrimp sample containing up to approximately 300 individuals was sorted to species. Northern Shrimp and Striped Shrimp were further divided into male, transitional, primiparous, multiparous or ovigerous stages based on characteristics according to Rasmussen (1953), Allen (1959) and McCrary (1971). These stages were further divided batches by disease condition, carapace condition and whether head roe was present. Each batch was weighted to the nearest 0.0001 kg. The oblique carapace length (CL) of all Northern Shrimp and Striped Shrimp individuals within each batch was measured by digital callipers and electronically recorded to the nearest 0.01 mm.

At the Freshwater Institute in Winnipeg, juvenile shrimp samples were thawed, weighed then divided into component parts and shrimp processed as described above. All other components were broken down to species, weighted and counted.

BIOMASS ESTIMATION

Three categories of biomass for Northern Shrimp and Striped Shrimp were calculated from the observed survey catch; total, fishable and female spawning stock. Total biomass includes all individuals. Fishable biomass is considered to be all females and all males greater than 17 mm CL. Female spawning stock biomass (SSB) is all females present in the catch.

Regardless of the type of biomass, the estimate was calculated in the same way. Shrimp of a particular species and biomass type caught at a sampling station in kilograms per square kilometre was calculated as:

$$ShrimpCatch = \frac{ShrimpWt \times BumpFactor}{SweptArea}$$

The bump factor is the ratio used to raise the shrimp sample to that of the full catch for the station by;

$$BumpFactor = \frac{CatchWt}{SubsampleWt} \times \frac{SubsampleWt}{\sum_j ComponentWt} \times \frac{ShrimpSampleWt}{ShrimpSubsampleWt} \times \frac{ShrimpSubsampleWt}{\sum_l ShrimpSpeciesWt}$$

where

Catch Wt is the portion of the catch weighed as a whole prior to sorting,

Subsample Wt is the portion of catch randomly selected to be sorted into j component parts, usually species or higher group, each weighed separately,

Shrimp Sample Wt is the weight all shrimp sorted from the total catch or subsampled catch,

Shrimp Subsample Wt is the portion of the Shrimp Sample before it is sorted into single shrimp species, Shrimp Species Wt is the total weight of an individual shrimp species.

The biomass estimates for the survey area are calculated by;

$$Biomass = \sum_k \left(\frac{\sum_s ShrimpCatch_{st}}{n_t} \times StratumArea_t \right)$$

Where, s is one station of n_t stations sampled in stratum t of which there are k strata within the survey area.

Upper and lower confidence intervals (CI) were estimated by resampling statistics (Bruce et al. 2000). CIs reported in the 2008 and 2010 Science Advisory Reports (DFO 2008; DFO 2010) were a summation of all individual stratum CIs in the survey area. The 2011 Zonal Assessment Process concluded this was not the correct approach. The approved method was to resample from the observed catch with replacement to produce a biomass estimate for the survey area as described above. A set of 15,000 estimates was produced from additional runs based on a new sampling of the observed catch with replacement, then sorted in ascending order. The estimate at the 2.5 and 97.5 percentiles of all runs were considered the 95% CI for the biomass estimate. CIs reported here have been adjusted to the new methodology and will therefore be different from those in the SARs. Biomass point estimates are not affected.

PRECAUTIONARY APPROACH FRAMEWORK

Shrimp in the EAZ are assessed with in a Precautionary Approach Framework (DFO 2007) with reference points developed during two workshops which included Science, Fisheries Management and stakeholder representatives (DFO 2009). The Upper Stock and Limit Reference Points agreed upon were 80% and 30% of the geometric mean of available biomass data. The reference points were first developed for SFA2 which at the time included three surveys conducted in 2006-2008. The SFA2 reference points were transferred unchanged for the EAZ at the 2011 ZAP.

TEMPERATURE

Contour plots of bottom temperature were produced by kriging mean bottom temperature data collected at each station using Surfer® Ver. 8 (Golden Software 2002).

COMMERCIAL FISHERY DATA

Catch per Unit Effort (CPUE) was calculated from observer catch data for directed fishing of Northern Shrimp or Striped Shrimp. Catch was the total catch, retained and discarded, reported. Effort was the total number of hours the trawl was towed. Effort of twin or triple trawls was considered as two or three times, respectively, the tow time recorded. Standard parametric statistics were used to produce an average CPUE and 95% confidence interval by management year within each assessment area.

RESULTS AND DISCUSSION

EASTERN ASSESSMENT ZONE

Survey Area Results

Survey Progress

The survey in 2011 was conducted aboard the fishing vessel Cape Ballard. The crew first completed the survey of SFA2EX from 3-18 August. 120 stations of the 121 allocated were sampled. One station had to be removed from the database during QC because the weight of the shrimp sample was not recorded making it impossible to scale to the full catch. The survey of RISA completed all 60 stations assigned from 18-24 August.

The fishing vessel Aqviq replaced the Cape Ballard in 2012. In 2012, the survey began in SFA2EX on 3 August and was completed on 24 August. All 121 stations allocated in the design were sampled. So that RISA was sampled during a neap period, it was sampled 6 to 12 August. Only 52 of the 60 stations allocated in the design were sampled. Six stations in the three northernmost strata of RISA-W could not be accessed because of ice in the area. Two stations had to be removed during quality control (QC) of the database. One tow never reached bottom. The other tow, while recorded as ten minutes in length, was actually only eight minutes long so had to be removed not having reached the minimum required by the sampling protocol.

SFA2EX P. borealis *Biomass and Distribution*

In 2012, the distribution of *P. borealis* catch (Fig. 3) has remained consistent with that seen in previous surveys. The main concentrations have been found in more or less a continuous band which follows the 300-400 m strata. Only minor contributions to the overall biomass come from the 100 m above or below the 300-400 m contour range (Fig. 4). The 100-200 and 500-750 m contribute very little to the overall survey area biomass.

Total, fishable and SSB indices have remained fairly stable over the time series (Fig. 5). For the period of 2009-2012, the total and fishable biomass has varied without trend and appears to fluctuating about the long-term mean. SSB shows a slight upward trend over 2009-2012 but there is no significant difference in year to year estimates.

SFA2EX P. montagui *Biomass and Distribution*

In 2012, only small catches of *P. montagui* were taken in SFA2EX mainly in the southwest part of the survey area (Fig. 6), a pattern consistent with previous surveys. The species is mostly found in the inshore 200-400 m depth strata.

With the exception of 2009, total, fishable and SSB biomass of *P. montagui* has been consistently low (<1200 t; Fig.7).

RISA P. borealis *Biomass and Distribution*

In 2012, the largest catches of *P. borealis* come from the western side of RISA-E near Resolution Island (Fig. 8). In RISA-E, the *P. borealis* depth distribution shifted to shallower depths in 2011 where it remained in 2012 (Fig. 9). The three year prior to 2011 show a consistent pattern concentrated in the 300-400 m strata. In RISA-W, *P. borealis* have been found in deeper water, 400-500 m, in 3 of the 5 years available.

The majority of *P. borealis* biomass comes from RISA-E and has varied without trend since 2007 (Fig. 10). While not significantly different, the 2008 and 2012 values are lower than the intervening years. RISA-W shows the opposite pattern (Fig. 11). While not significantly different from each other the 2008 and 2012 surveys in RISA-W are significantly higher than the intervening years.

RISA P. montagui *Biomass and Distribution*

In 2012, by far the large catches of *P. montagui* were found in RISA-W west of the Button Islands and west of Resolution Island (Fig. 12). There is no consistent pattern to the depth distribution of *P. montagui* in RISA-W (Fig. 13). In RISA-W, *P. montagui* are predominantly found in shallower strata of 200-300 m depth however the absolute density varies greatly year to year (Fig. 13).

P. montagui biomass has trended downward in RISA-E for the years 2008-2012 (Fig. 14). In RISA-W, *P. montagui* biomass had been stable from 2008 varying without trend until the 2012 survey where it sharply increased to about 4 times the next highest biomass observed in the time series (Fig. 15). Given the highly energetic area (Drinkwater 1986, Hudon 1990) and the large *P. montagui* population just to the west of RISA-W the increase could indicate an eastward shift in the population. The cooler bottom temperatures in RISA-W observed in 2012 would be more favourable for *P. montagui*. But since the 2012 estimate is so different from others in the time series, 2012 may be a year-affected survey and should be used with great caution for fishery management purposes. No conclusive explanation for such a large increase has been identified. Only additional surveys will confirm whether the increase is real and should be included as an indicator of stock status or an estimate which should be ignored.

Assessment of the EAZ

Bottom Temperature

The temperature regime in the EAZ for 2012 overlain by *P. borealis* catches is shown in Figure 16. *P. borealis* can be found at temperatures of below zero to over 4°C in the EAZ, however, the largest catches tend to come from water temperatures in the 1-3°C range.

In 2012, *P. montagui* catches in relation to bottom temperatures in the EAZ are shown in Figure 17. *P. montagui* prefer cooler water than *P. borealis* and are rarely found in water temperatures greater than 2°C.

Area-weighted mean bottom temperatures for the EAZ increased by over a degree from 2009 to 2010 (Fig. 18). With its larger area, the EAZ index closely follows that seen in the SFA2EX index. The temperature remained at this higher level in 2011 but declined in 2012 back to the levels seen in the surveys of 2006-2010. Temperature in RISA for 2010 and 2011 are at levels that are less favourable for *P. montagui* and may be affecting the distribution of this species in the area. In 2012, the closer to preferred temperatures in RISA may explain, at least partially, the return of *P. montagui* in 2012 especially in RISA-W.

Eastern Assessment Zone – *P. borealis*

Total, Fishable and SSB Biomass of *P. borealis* have varied without trend in the EAZ since 2007 (Table 1; Fig. 19). Mean fishable biomass was 67,987 t for the period 2008-2012 with the latest estimate being 60,534 t for 2012. SSB was 39,800 t and 41,190 t for the same time periods respectively.

Recruitment of *P. borealis* in the EAZ is uncertain (Fig. 20) because very few individuals between 11.5 and 17 mm are collected within the codend of the Campelen trawl (Fig. 21). Occasional recruitment pulses are seen such as in 2006 and 2009 but still very low abundance in comparison to the adults in the same area. The signal from the Linney Bag attached to the outside of the trawl indicates a greater proportion of recruit and pre-recruit sized shrimp are present in the system than seen from the codend

catch (Fig. 22). More recruitment seems to have occurred earlier in the survey series with the last noticeable young-of-the-year seen in 2010.

Length frequencies of both males and females in the EAZ have been quite broad over the time series with the center of the distribution stable for from 2006 to 2011 (Fig. 21). In 2012, male length distribution narrowed and shifted slightly to larger individuals with almost no male present below 18 mm. Should this persist the prospects for future reproductive capacity may be poor.

Commercial fishing in the EAZ began in the late 1970s in the northeast of SFA2EX. Catch was low until 1988. A quota of 3,500 t was introduced in 1989 (Table 3; Fig. 23). Catch declined to near zero in 1993 after which it increased steadily for the next four years as the captains learned where to best prosecute the fishery in SFA2 i.e., in the area east of Resolution Island. In 1997, the quota increased by 1,750 t which increased catch to 6,359 t that year. Catches have remained relatively stable fluctuating near 6,000 t through the 2009/10 fishing season. Increased effort in SFA2EX saw the catch in the EAZ reach an all-time high in 2011/12 of 7,423 t. The bulk of the catch each year is taken from a very small area east of Resolution Island.

Dividing the catch reported by the fishable biomass produces an exploitation rate for the zone (Fig. 24). Two rates, actual and potential, have been calculated for the EAZ because TAC has rarely been taken over the history of the fishery and never since survey data became available for comparison. The actual exploitation rate has varied without trend with a mean of about 9% from 2008/09 onward (Fig. 24a). The available quotas if taken produce a higher potential exploitation rate mean of about 14% over the same period (Fig. 24b).

The composition of the catch in the EAZ had been predominantly female from 2003/04 to 2009/10 (Fig. 25). For the last three years, however, the composition in the sets has been nearer to being equal proportions of males and females. Overall there is a slight negative trend in average size of the sexes caught by the commercial trawls (Fig. 26). The large increase in 2012/13 may be due to the low number of observed sets for length distribution for analysis in this assessment. Also these sets would have come from early in the fishing season which may have also biased result. The downward trend mirrors the decline in lengths especially for females observed in the survey. Negative trends may suggest a fishing effect but this is complicated by the effects large cohorts and the sex change of shrimp may have on the trend.

While the *P. borealis* resource in the EAZ for 2012/13 is down slightly, it remains well within the Healthy Zone of the PA Framework established for the zone (Fig. 31). The current TAC produces an exploitation rate of about 14% well within the norm expected by fishery managers.

Eastern Assessment Zone – *P. montagui*

For *P. montagui*, total, fishable and SSB biomass all spiked in 2012 because of the large increase in RISA-W already discussed above (Fig. 28).

P. montagui recruitment in the EAZ is uncertain (Fig. 29) for much the same reasons as for *P. borealis,* however the proportion of recruitment sized individuals appears greater for *P. montagui* (Fig. 30). *P. montagui* within the Linney Bags show a stronger signal of recruit and pre-recruit sized shrimp (Fig. 31) although no young-of-the-year were found in the samples. The relative abundance of males and females appear to alternate yearly in the survey series (Fig. 30). The observation seems to indicate male conversion to females does not occur regularly but in a biennial fashion. It is unknown whether this is a sampling artifact or a life history characteristic in the EAZ. To my knowledge this has not been seen in other *P. montagui* populations though this species is rarely studied in comparison to *P. borealis*.

Quota has been part of the fishery in the EAZ since its beginning with 100 t available in 1978 (Fig. 32). Quotas have increased several times and new access added through special allocations since then but catch has rarely achieved the available quota in the zone. It is unclear whether the large catch over runs in 1995-1997 is real because of discrepancies between Canadian Atlantic Quota Report (CAQR) reported catch and observer records. Figure 32 shows the observer records so as this is the best way to convert past catch to the new EAZ area. CAQR records do not show these large over runs (Table 4). What is more in agreement between the two records is the general decline in catch from about the year 2000 to 2011/12. Since much of the quota for *P. montagui* is considered by-catch taken during the prosecution of

the *P. borealis* fishery, two factors are believed to contribute to the decline in catch. First, fishing Captains indicate increased knowledge of indicators such as water temperature and seasonality that affect shrimp distributions i.e. they have learned to be able to avoid *P. montagui* using these indicators. Second, The Nunavut Land Claims Agreement came into effect in 1999 which placed a new jurisdictional boundary within SFA2. This boundary moved the offshore industry fleet to the east of where they had normally fished. Given the distribution of *P. montagui* this moved the fleet into waters where this shrimp was less abundant naturally reducing its by-catch as a result. It is not believed therefore that the reduction is catch is an indicator of stock status. The increase seen 2012/13 is a mainly result of additional effort in the EAZ south and west of Resolution Island stemming from survey results in the WAZ to the west and changes coming into effect for the management of the shrimp fishery within the region.

Comparing the *P. montagui* catch in the EAZ to its fishable biomass produced a reported exploitation rate that has hovered around the long term mean of 5.8% from 2008/09 to 2012/13 (Fig. 33). The potential exploitation rate, based on the summation of all quotas in the zone, has a much higher mean of 52.4% over the same time period (Fig. 33a). The Potential exploitation rate was down sharply in 2012/13 because of the large spike in fishable biomass observed by the survey (Fig. 33b). Caution must be taken in thinking this is an improvement in status as the spike may be a year affect since the estimate is so anomalous when compared to the rest of the time series. Results of future surveys will be required to the reality of the 2012/13 estimate.

The mean length of *P. montagui* caught by the commercial fishery from 1996 on is shown in Figure 34. Overall years, males showed wide oscillations in mean length with a very large drop in 2012/13 (Fig. 34a). Survey mean length showed a similar trend in the 2006 to 2012 surveys but without major decline in 2013. The difference is likely due to the limited number of *P. montagui* sets that are sampled by observers for length frequency. Therefore the 2012/13 commercial mean is not a concern. Females caught in the commercial fishery show an overall negative trend in mean length (Fig. 34b). The survey results show a similar trend during the first five years but diverge in the last two. While the there was a sharp decline in 2012/13 in the commercial catch it magnitude was much less than seen in the males. Survey results contract the decline in females in 2012 so again likely the result of too few sets sampled by the observers that year.

The spike in *P. montagui* biomasses in 2012 has moved the resource out of the Cautious Zone of the PA Framework where it had been in 2011/12 and 2010/11 into the Healthy Zone well above the USR (Fig. 35). Great caution must be taken in interpreting this as a significant change in the status of *P. montagui* in the EAZ given the uncertainty of the 2012 estimate in the time series. Since the TAC has already been set for *P. montagui* for the 2013/14 fishing seas as part of the conversion of the management of the Eastern and Western Assessment Zones the 2012 survey result and its usefulness in setting the TAC is moot. Fortunately this allows the 2013 survey results to be added to the time series and the 2012 judged in that light before it is used in determination of a TAC.

Some caution should be taken when interpreting the EAZ PA Frameworks. The reference points were based on the 2006-2008 survey results. This is a short time series with the first two years now considered invalid in the time series because of performance issues set coverage in the initial surveys conducted in RISA in 2006 and 2007. Without the historical context of a longer time series it is unknown whether the EAZ is currently within a productive period or not. In addition the reference points were developed for SFA2 not the EAZ. New reference points should be developed representative of the EAZ based on the most reliable data available. This has been raised as an issue at previous ZAPs but found little traction to change the reference points.

CPUE was low in the first decade or so of the fishery for *P. borealis* in the EAZ (Fig. 36). As quotas increased and the most productive fishing locations found CPUE increased steadily from 1994 to 2000 where it leveled off through to the 2008/09 fishing season. CPUE jumped up to a new plateau the following year where it has remained since. No explanation for this higher rate in the last four years has been determined.

The CPUE from the P. montagui fishery in the EAZ is shown in Figure 37. P. montagui fishing in the EAZ is a mix of directed and by-catch fishing, also changes in the price differential of the two shrimp species and their marketing make CPUE problematic to calculate and especially hard to interpret. As I understand the process, observers record the directed species of a set based on which species exceeds 50% of the

shrimp catch. Since CPUE only makes sense in a directed fishery, this leaves other *P. montagui* catch out of the overall CPUE calculation. CPUE is included here as industry requests the information but it is not believed to indicate status of either shrimp species resource but rather more reflective of fishing behaviour within the EAZ.

WESTERN ASSESSMENT ZONE

Survey Progress

Since the Monitoring Update (DFO 2012), no new survey information is available for the Western Assessment Zone. Biomass and exploitation data are included here for the purpose of creating reference points for a Precautionary Approach Framework for the zone.

Reference Points

Reference points for the WAZ were created with the same methodology used in SFAs 2 and 4-6 (DFO 2009) i.e., 30% and 80% of the geometric mean female spawning stock biomass represents the Limit Reference Point (LRP) and Upper Stock Reference (USR) respectively.

P. borealis Biomass and Exploitation

Total, Fishable and Female Spawning Stock biomasses are showing a positive trend over the three surveys conducted albeit year to year differences are not significant (Fig. 38). Very little *P. borealis* has been caught in the WAZ so the actual exploitation rate is very low. Only the borealis by-catch quota of 400 t can potentially be caught in the WAZ which if taken would result in a low exploitation rate less than 3% (Fig. 39).

P. borealis PA Framework

Using the three survey estimates available, the LRP was calculated to be 1,288 t with an USR of 3,434 t. The *P. borealis* resource in the WAZ for 2012/13 was well within the Healthy Zone of the PA framework (Fig. 40).

P. montagui Biomass and Exploitation

Total, Fishable and Female Spawning Stock biomasses varied without trend over the three surveys conducted (Fig. 41). Very little *P. montagui* has been caught in the WAZ so the actual exploitation rate is very low. Two quotas can potentially be fished in the WAZ totalling 1,400 t which if caught would result in a low exploitation rate less than 3% (Fig. 42).

P. montagui PA Framework

The USR was calculated to be 3,434 t based on the results of the three surveys conducted. The *P. montagui* resource for 2012/13 was well within the Healthy Zone of the PA framework (Fig. 43).

P. montagui Catch per Unit Effort

The WAZ has been fished sporadically from 1979-1991 and only once again until the 2010/13 fishing season (Fig. 44). Results of the 2007 and 2009 surveys renewed interest in the area with catches increasing each year for the last three seasons. CPUE has increased accordingly as the industry re-learns where to fish in the areas and does not appear to reflect stock status.

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TABLES AND FIGURES

Table 1. Total, fishable and female spawning stock biomass and abundance estimates for Pandalus borealis in the Eastern Assessment Zone for the 2006-2012 surveys. LCI and UCI represent the 95% confidence range.

		Weight (tonne)		
Year	**Biomass**	**Mean**	**LCI**	**UCI**
2012	Total	60985.45	43497	80408
2011	Total	83461.84	23956	143793
2010	Total	71887.38	41392	108846
2009	Total	81363.27	51479	113556
2008	Total	51581.26	37757	67137
2007	Total	43827.19	31480	58333
2006	Total	33633.55	22700	45511
2012	Fishable	60533.67	43074	79960
2011	Fishable	78530.23	23900	135037
2010	Fishable	71064.51	40234	108703
2009	Fishable	78754.88	48850	110115
2008	Fishable	51053.43	37117	66708
2007	Fishable	43305.97	31015	58346
2006	Fishable	32815.89	21969	44152
2012	Female SS	41189.85	29498	54383
2011	Female SS	47806.80	13470	82926
2010	Female SS	43800.31	19025	79665
2009	Female SS	38856.32	23122	56820
2008	Female SS	27653.12	22507	39368
2007	Female SS	27698.44	19249	39007
2006	Female SS	16805.06	10523	23026

Table 2. Total, fishable and female spawning stock biomass and abundance estimates for Pandalus montagui *in the Eastern Assessment Zone for the 2006-2012 surveys. LCI and UCI represent the 95% confidence range.*

		Weight (tonne)		
Year	**Biomass**	**Mean**	**LCI**	**UCI**
2012	Total	29966.61	8922	50956
2011	Total	8729.02	3266	16395
2010	Total	7860.38	6089	9795
2009	Total	17437.62	7427	32323
2008	Total	16088.04	8421	23642
2007	Total	7587.20	4378	11042
2006	Total	2833.27	255	5412
2012	Fishable	28845.47	8582	48946
2011	Fishable	7739.99	2871	14285
2010	Fishable	7422.75	5714	9290
2009	Fishable	15679.12	6190	29774
2008	Fishable	14667.04	7287	21973
2007	Fishable	4828.25	3389	6673
2006	Fishable	2667.14	210	5122
2012	Female SS	23552.02	6218	40985
2011	Female SS	3124.24	1599	4721
2010	Female SS	5819.1	4509	7136
2009	Female SS	8775.54	4205	13955
2008	Female SS	10659.82	4269	17047
2007	Female SS	1970.63	903	3490
2006	Female SS	2134.38	50	4219

Table 3. Quota, adjusted quota (after bridging) and catch reported by CAQR for Pandalus borealis *in SFA 2 and 3.*

	Shrimp Fishing Area or Quota Area								
	SFA2EX			SFA2CM			SFA3[2]		
Management Year[1]	Initial Quota (t)	Adjusted Quota (t)	Catch (t)	Initial Quota (t)	Adjusted Quota (t)	Catch (t)	Initial Quota (t)	Adjusted Quota (t)	Catch (t)
1988						2826			
1989				3500		3039			
1990				3500		1771			
1991				3485		1098			
1992				3485		1239			
1993				3485		106			
1994				3500		475			
1995				3500		2721			
1996				3500		3968			
1997				5250		5235			
1998				5250		5163			41
1999	3500	3500	105	5250	5250	5027			0
2000	3500	3500	237	5353	5353	4024			0
2001	3500	3500	394	5250	5250	5435			0
2002	3500	3500	64	5250	5250	5533			0
2003/04	3500	3500	31	5250	5250	4792			0
2004/05	3500	3500	212	5250	5250	5019			0
2005/06	3520	3520	736	5253	5253	5466			0
2006/07	3480	3480	725	5247	5247	5241	400	400	90
2007/08	3500	3500	529	5250	5250	5781	400	400	406
2008/09	3500	3500	213	5250	5192	4898	400	400	0
2009/10	3500	3465	1030	5250	4660	4399	400	400	0
2010/11	3500	3483	802	5250	5797	5721	400	400	53
2011/12	3500	3201	2557	5250	5302	5298	400	400	161
2012/13[3]	3500	3763	654	5250	5329	4425	400	400	173

[1] Management Year changed from calendar to fiscal in 2003 so the during the conversion period the 2003/04 season is 15 months.
[2] *P. borealis* by-catch to be fished within SFA3 and SFA2 within the NSA while directing for *P. montagui.*
[3] CAQR as of 25 January 2013 may be incomplete as fishery on-going.

Table 4. Quota, adjusted quota (after bridging) and catch reported by CAQR for Pandalus montagui *in SFA 2 and 3.*

	Shrimp Fishing Area or Quota Area								
	SFA2[2]			SFA3[2]			2,3,4 Quota[3]		
Management Year[1]	Initial Quota (t)	Adjusted Quota (t)	Catch (t)	Initial Quota (t)	Adjusted Quota (t)	Catch (t)	Initial Quota (t)	Adjusted Quota (t)	Catch (t)
1978							100		0
1979							100		92
1980							200		236
1981							200		13
1982							200		0
1983							850		0
1984							850		0
1985							850		0
1986							850		476
1987							1200		1069
1988							1200		1125
1989							1200		1269
1990							2280		1635
1991							1190		605
1992							1190		0
1993							1190		0
1994							1200		244
1995							1200		245
1996							1200		0
1997							1200		435
1998				500		0	3300	3300	2205
1999				500		0	3300	3300	3714
2000				500		0	3300	3300	3005
2001				500		0	3300	3300	3751
2002	2000	2000	0	1000	1000	0	4300	4300	3369
2003/04	2000	2000	0	1000	1000	0	3800	3800	1053
2004/05	2000	2000	0	1000	1000	0	3300	3300	2069
2005/06	2000	2000	465	1000	1000	176	3300	3300	1658
2006/07	2000	2000	0	1000	1000	264	3300	3300	2167
2007/08	2000	2000	197	1000	1000	341	3300	3300	606
2008/09	2000	2000	0	1000	1000	0	3300	3300	645
2009/10	2000	2000	0	1000	1000	0	3300	3300	480
2010/11	2000	2000	23	1000	1000	310	3300	3094	554
2011/12	2000	2000	23	1000	1000	836	3300	2778	706
2012/13[4]	2000	2000	45	1000	1000	981	3300	3527	1229

[1] Management Year changed from calendar to fiscal in 2003. 2003/04 season 15 months during the conversion period.
[2] Nunavut special allocation. Quota to be fished in SFA 2 and 3 within the NSA only.
[3] *P. montagui* to be fished by license holders within SFA 2, 3 and 4 west of 63°W.
[4] CAQR as of 25 January 2013 may be incomplete as fishery on-going.

Table 5. Total, fishable and female spawning stock biomass and abundance estimates for Pandalus borealis *and* Pandalus montagui *in the Western Assessment Zone for the 2007, 2009 and 2011 surveys. LCI and UCI represent the 95% confidence range.*

		Pandalus borealis Weight (tonne)		
Year	Biomass	Mean	LCI	UCI
2011	Total	21491.90	13714	30399
2009	Total	18401.51	8760	30301
2007	Total	16120.80	5497	31243
2011	Fishable	19692.10	12468	27961
2009	Fishable	15543.95	7613	25529
2007	Fishable	14614.98	4907	28872
2011	Female SS	6376.60	4182	8909
2009	Female SS	3839.38	1154	7479
2007	Female SS	3231.03	1687	5361
		Pandalus montagui Weight (tonne)		
Year	Biomass	Mean	LCI	UCI
2011	Total	77142.30	45030	121559
2009	Total	65044.31	31655	112124
2007	Total	78064.38	19755	155041
2011	Fishable	71557.90	40264	108612
2009	Fishable	46672.87	25756	73342
2007	Fishable	54044.48	17007	99461
2011	Female SS	32549.40	20296	46119
2009	Female SS	17998.70	9775	28160
2007	Female SS	19277.30	5668	36606

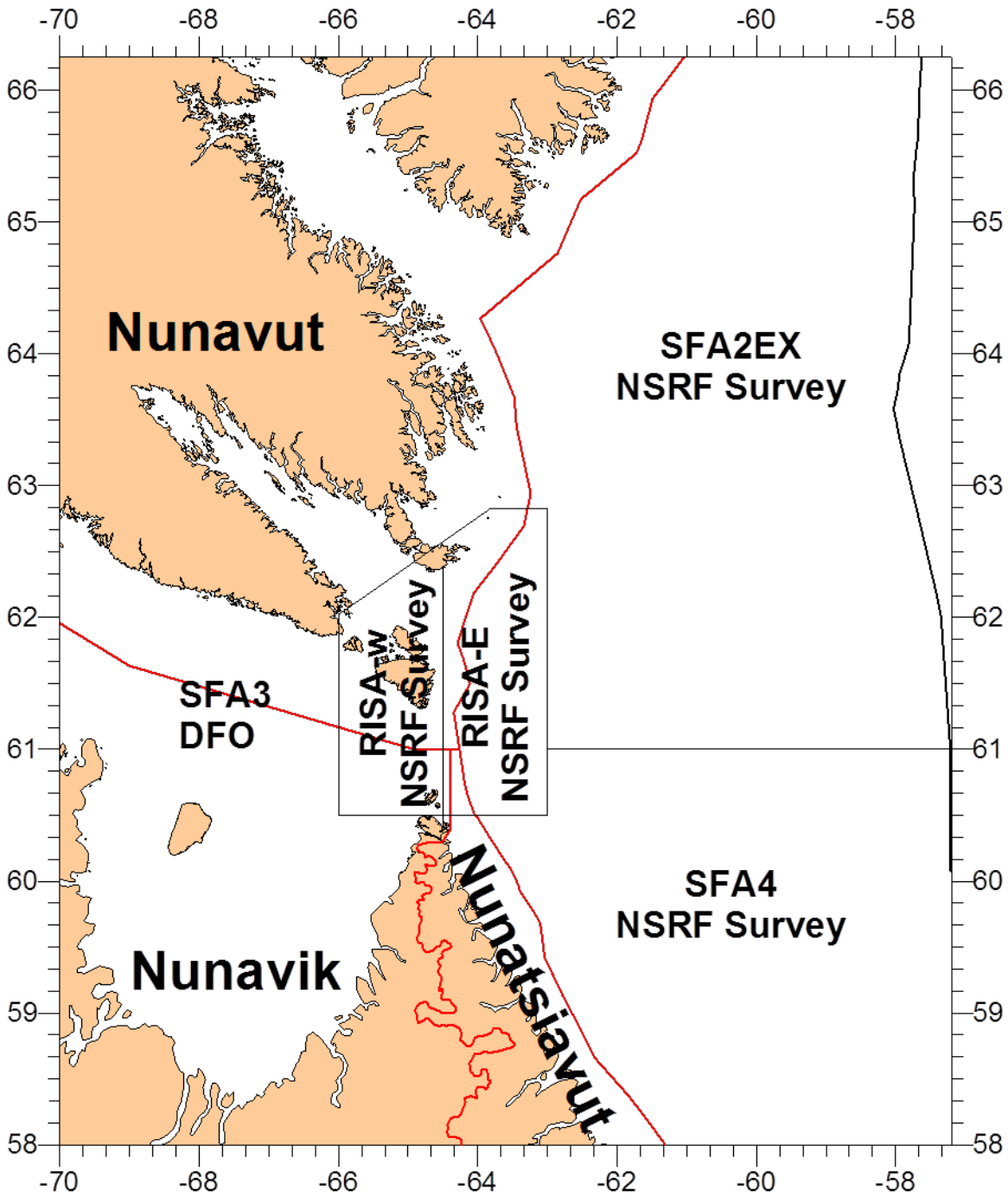

Figure 1. Location of the northern survey areas within the Eastern and Western Assessment Zones, Shrimp Fishing Area (SFA) 2 Exploratory (EX), Resolution Island Study Area (RISA)–East (E), RISA–West (W) and SFA 3, used in the assessment of domestic Canadian Pandalid Stocks by the Central and Arctic Region. Red line shows the borders of the Nunavut, Nunatsiavut and Nunavik Land Claim Areas.

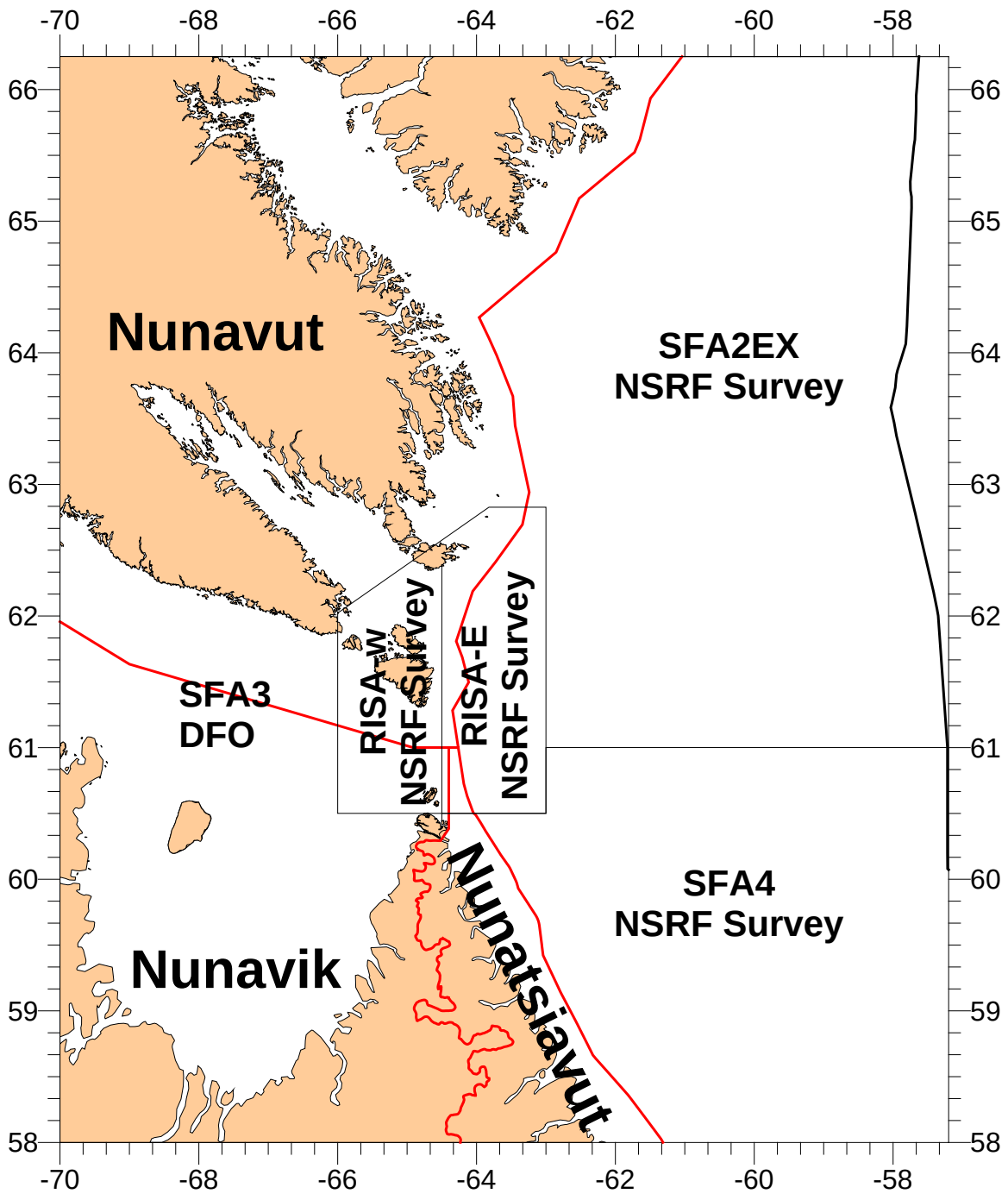

Figure 1. Location of the northern survey areas within the Eastern and Western Assessment Zones, Shrimp Fishing Area (SFA) 2 Exploratory (EX), Resolution Island Study Area (RISA)–East (E), RISA–West (W) and SFA 3, used in the assessment of domestic Canadian Pandalid Stocks by the Central and Arctic Region. Red line shows the borders of the Nunavut, Nunatsiavut and Nunavik Land Claim Areas.

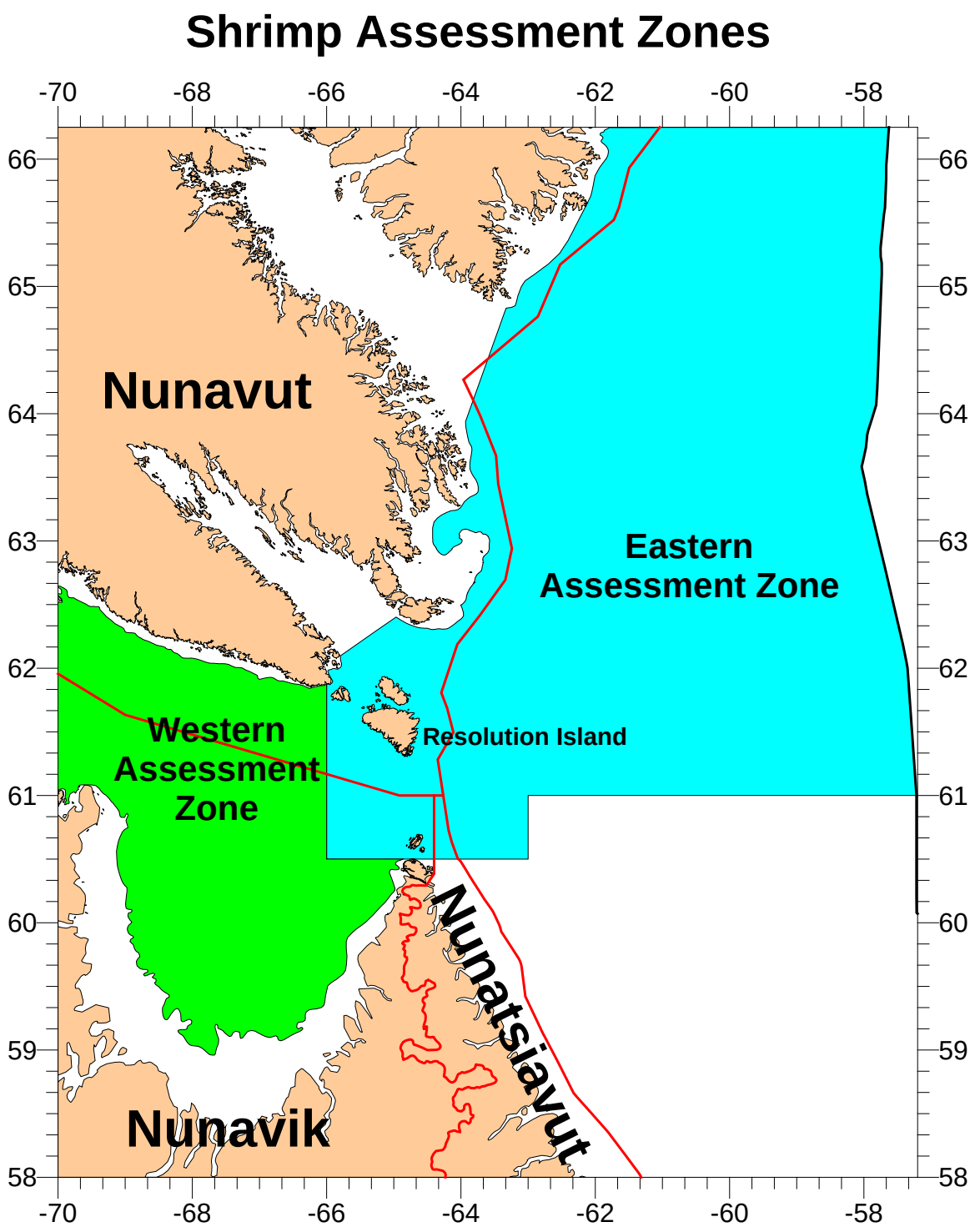

Figure 2. Location of the Eastern (blue) and Western (green) Assessment Zones. The Eastern Assessment Zone extent is equivalent to the areas of SFA2EX and RISA-E and RISA-W combined. The Western Assessment Zone if the same as the SFA 3 survey area.

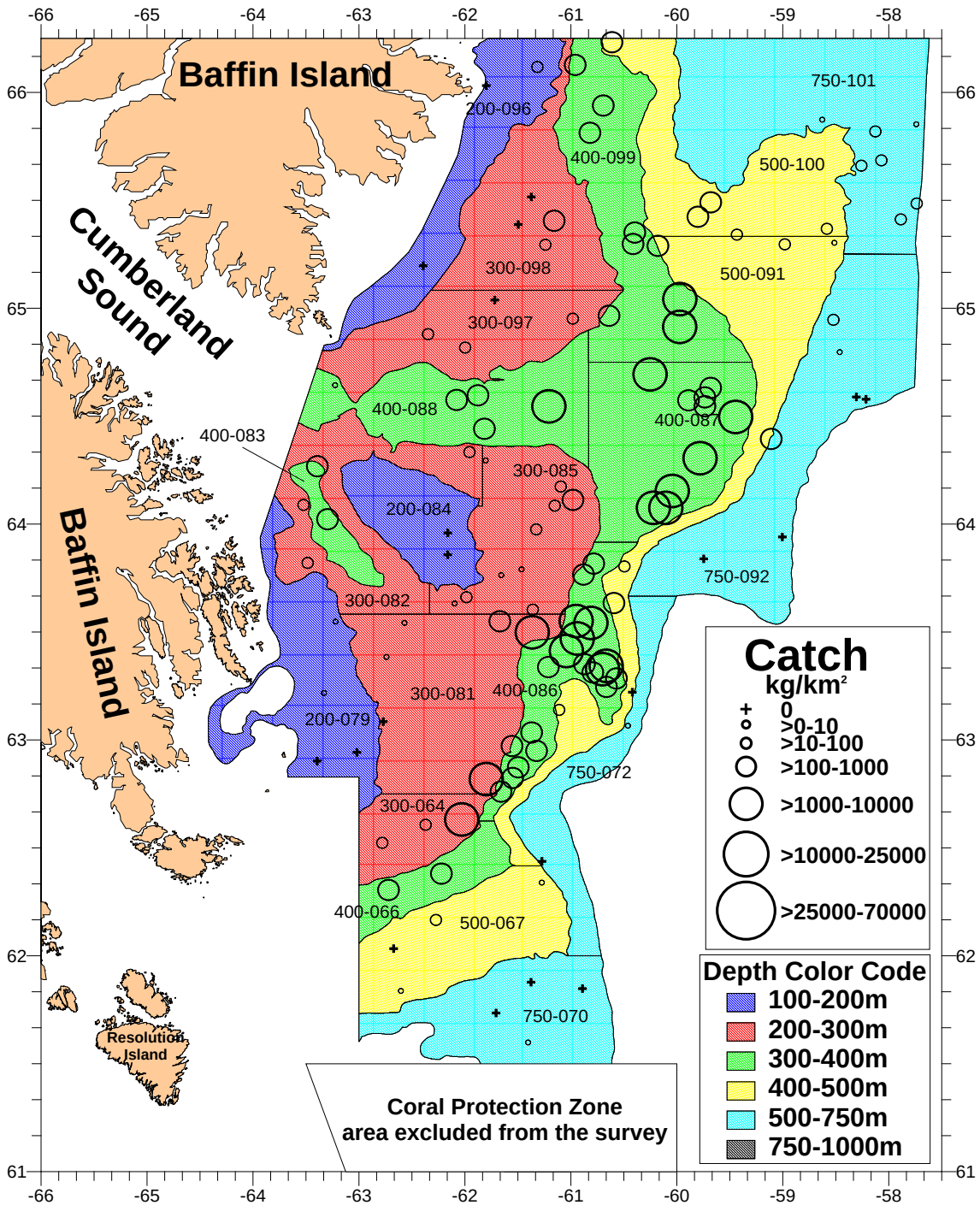

Figure 3. Standardized Pandalus borealis *catch from the 2012 SFA2EX survey area overlying the depth contours and strata of the survey area.*

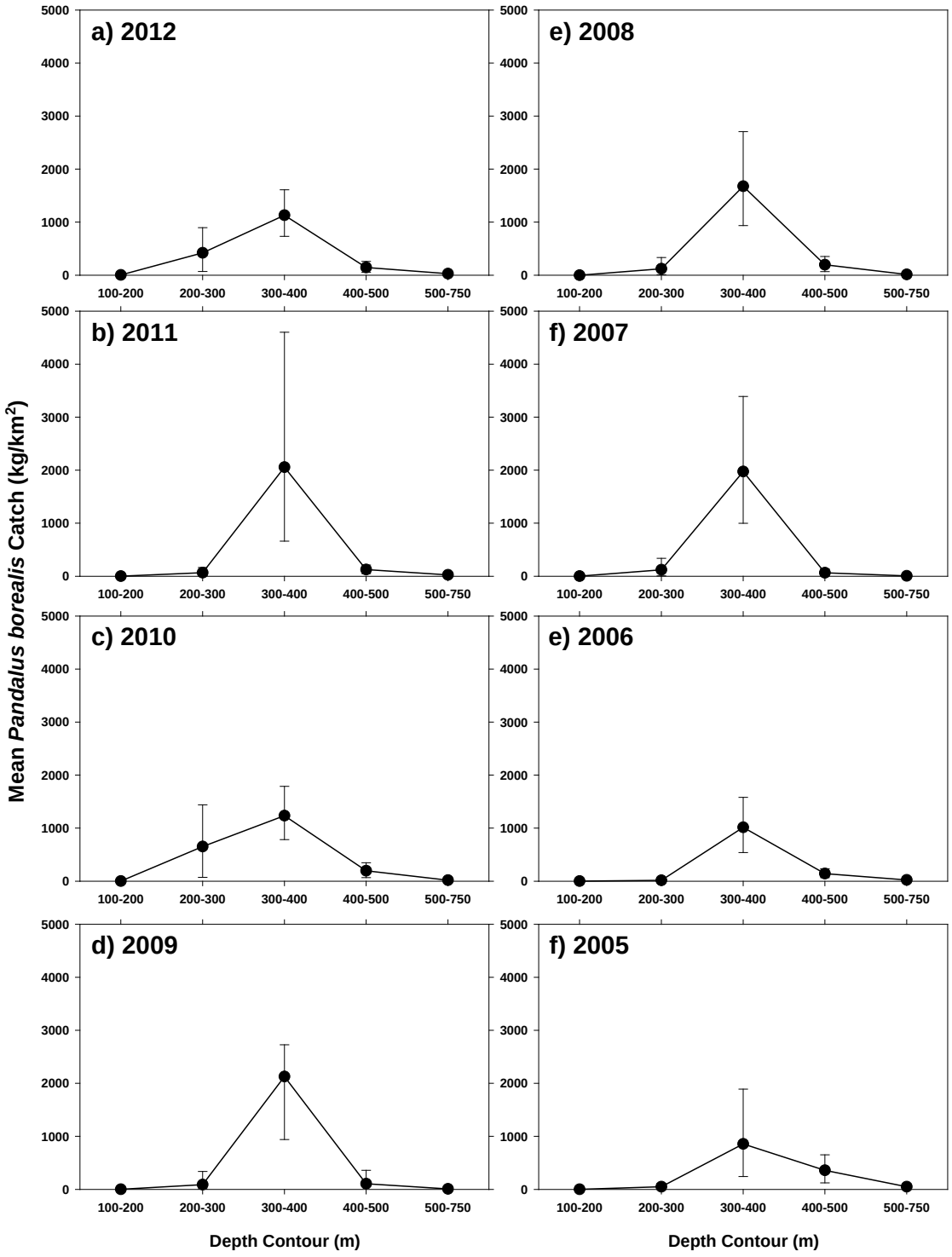

Figure 4. Mean Pandalus borealis *catch by depth contours in the SFA2EX survey area for the years 2005-2012.*

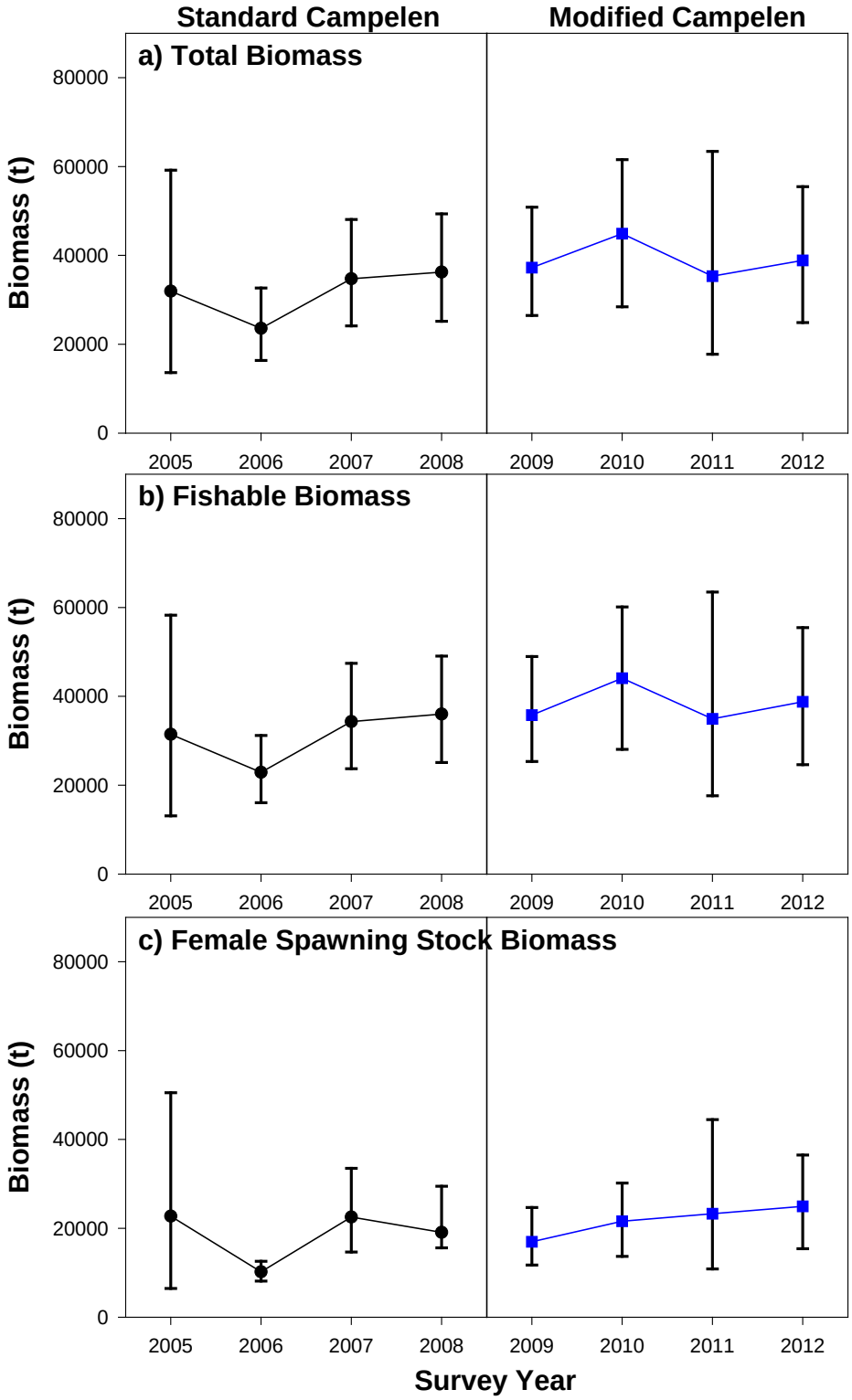

Figure 5. Fishable and female spawning stock biomass indices of Pandalus borealis *in the SFA2EX survey area for the years 2005-2012. Note the changes to the use of the modified Campelen trawl.*

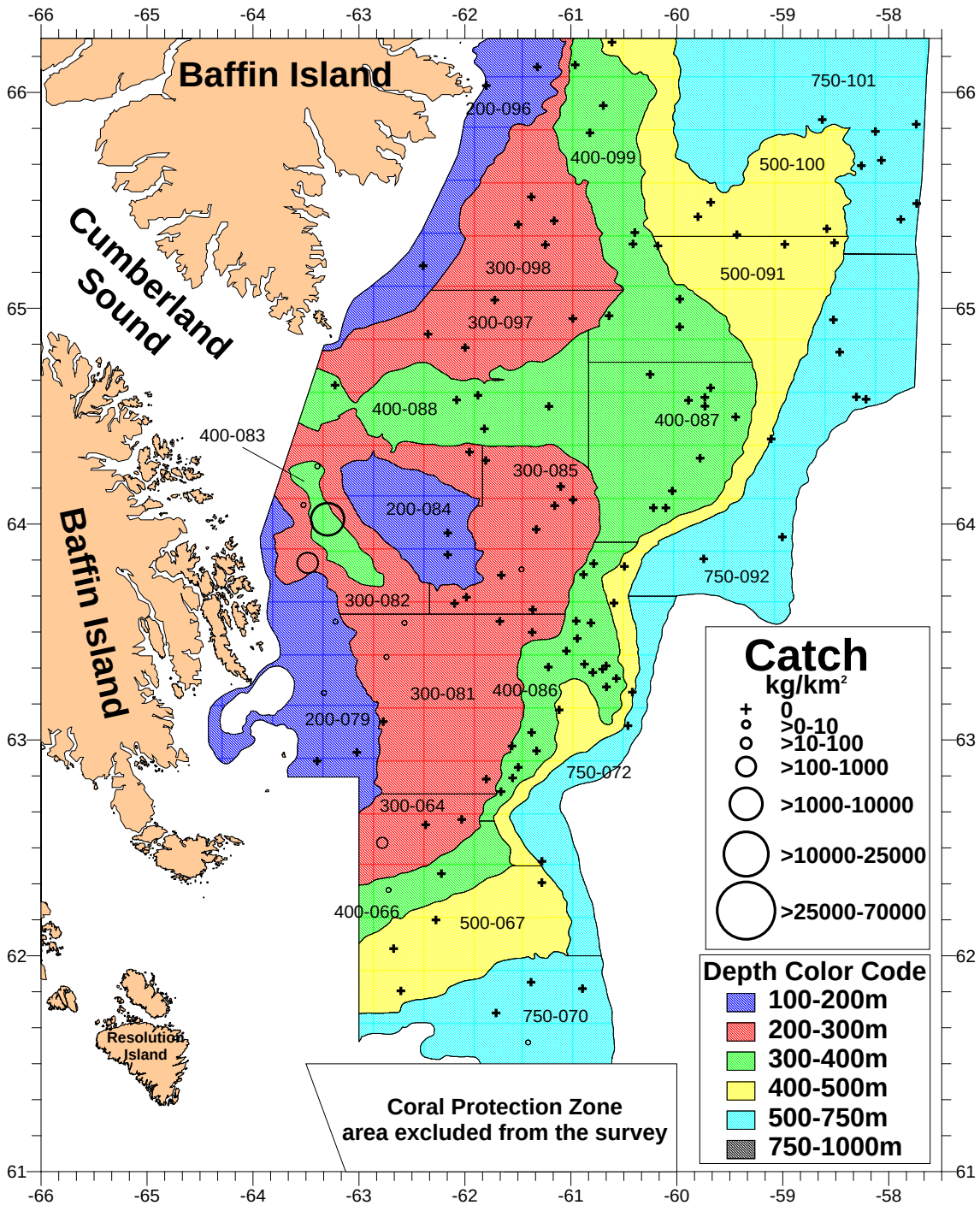

Figure 6. Standardized Pandalus montagui *catch from the SFA2EX survey area in 2012 overlying the depth contours and strata of the survey area.*

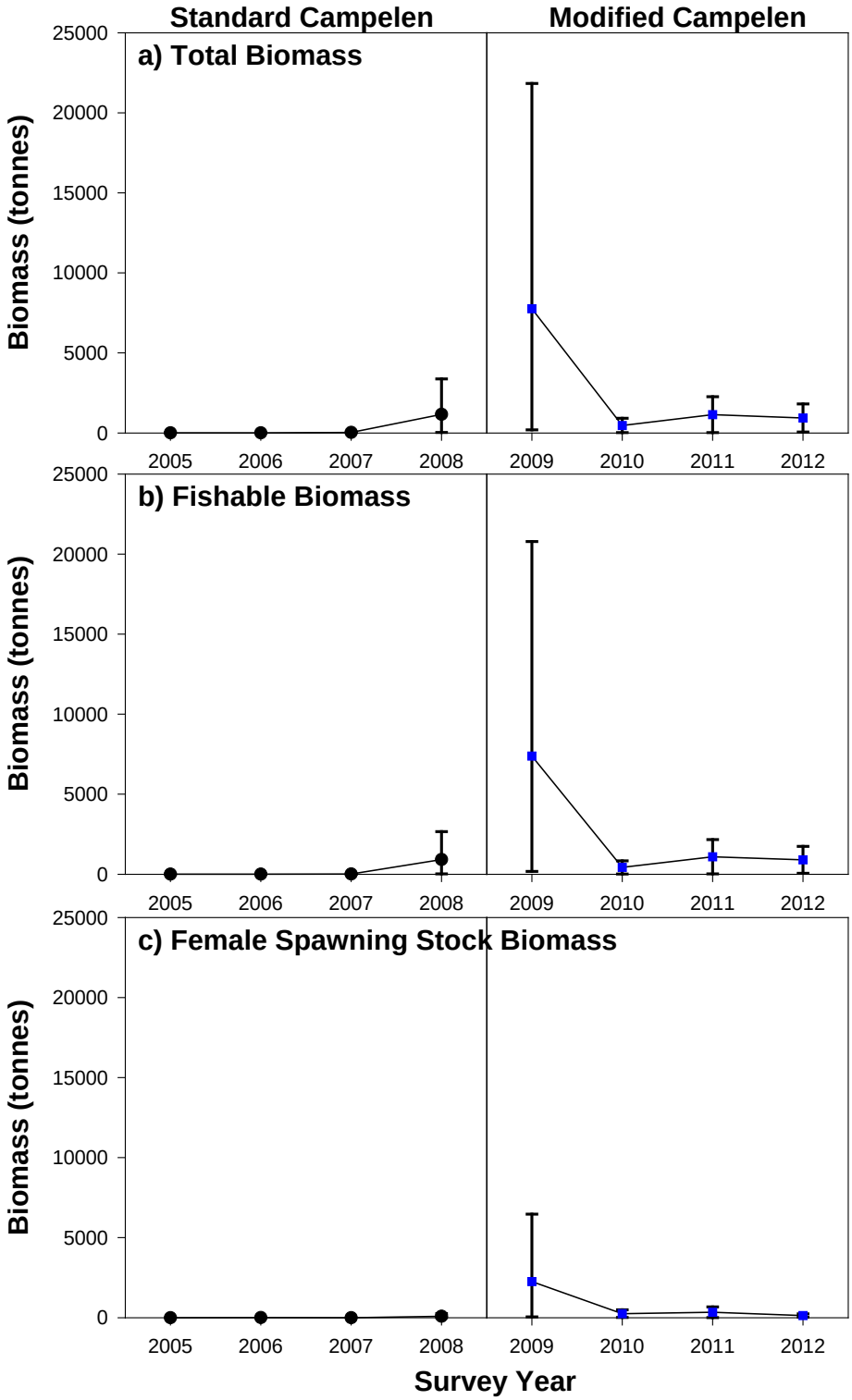

Figure 7. Total, fishable and female spawning stock biomass indices of Pandalus montagui *in the SFA2EX survey area for the years 2005-2012. Note the change to the modified Campelen trawl.*

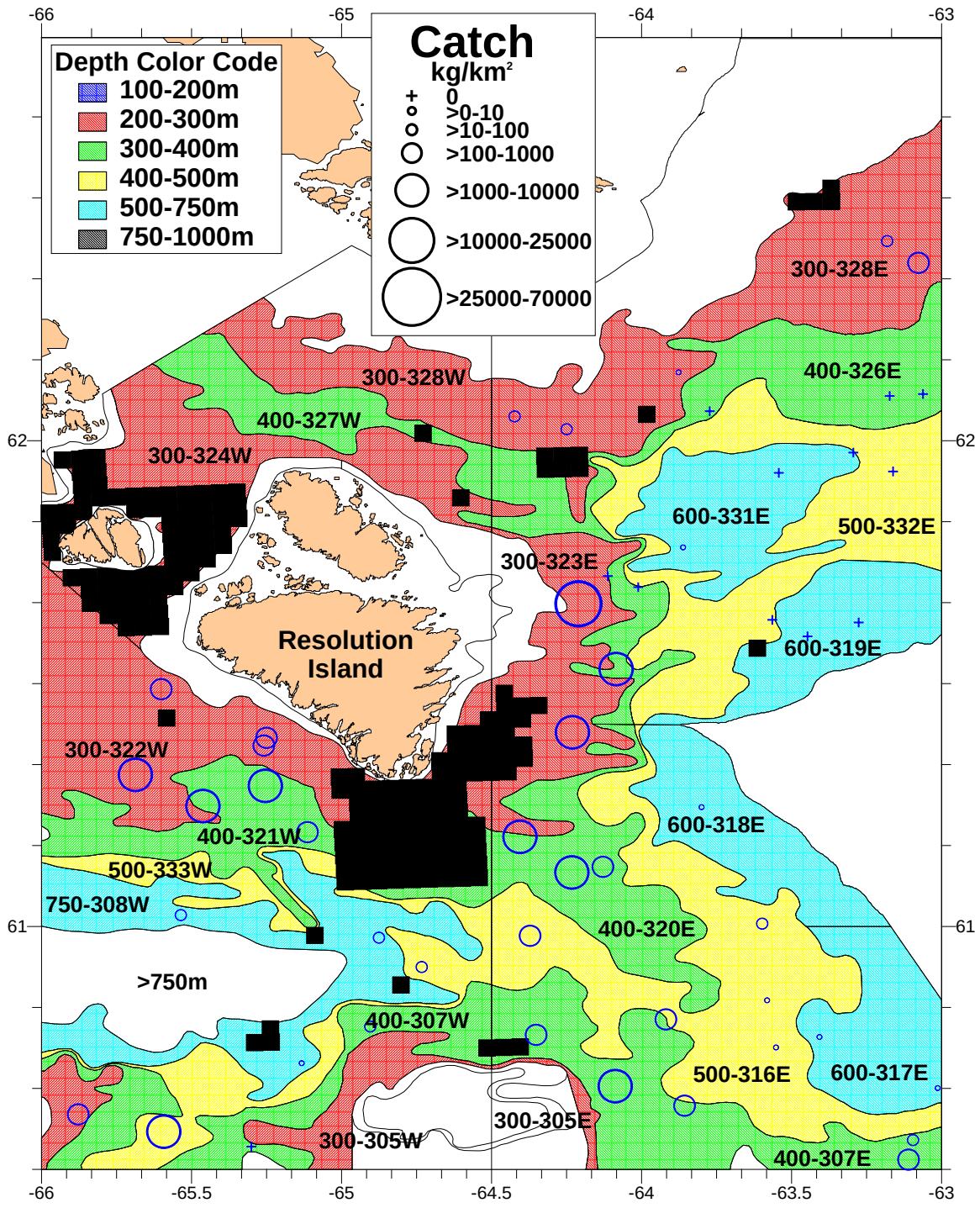

Figure 8. Standardized Pandalus borealis *catch from the 2012 RISA survey area overlying the depth contours and strata of the survey area. Blackened areas are cells removed from the survey design because of untrawlable bottom.*

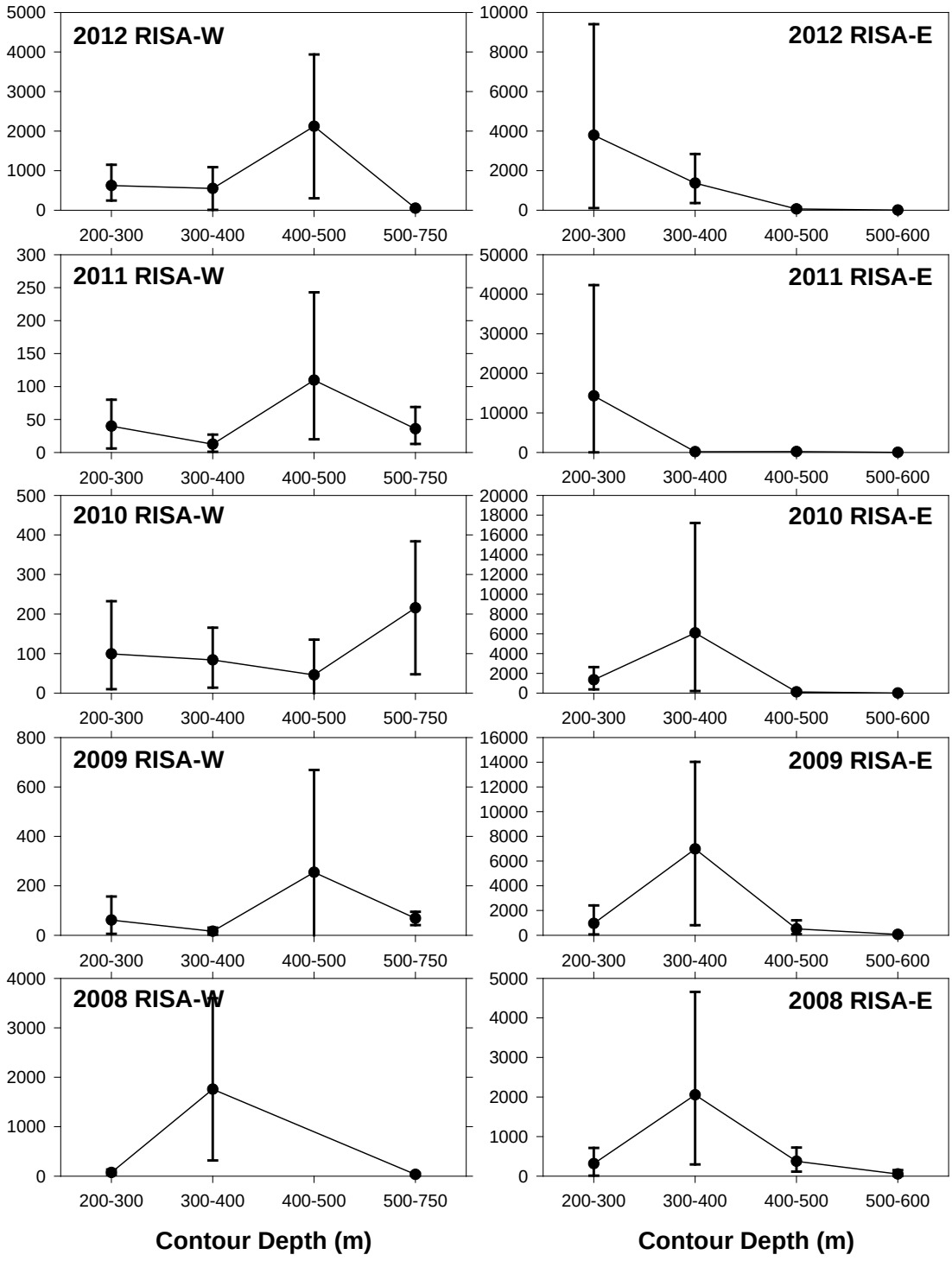

Figure 9. Mean Pandalus borealis *catch by depth contours in the RISA-East and RISA-West survey areas for the years 2008-2012.*

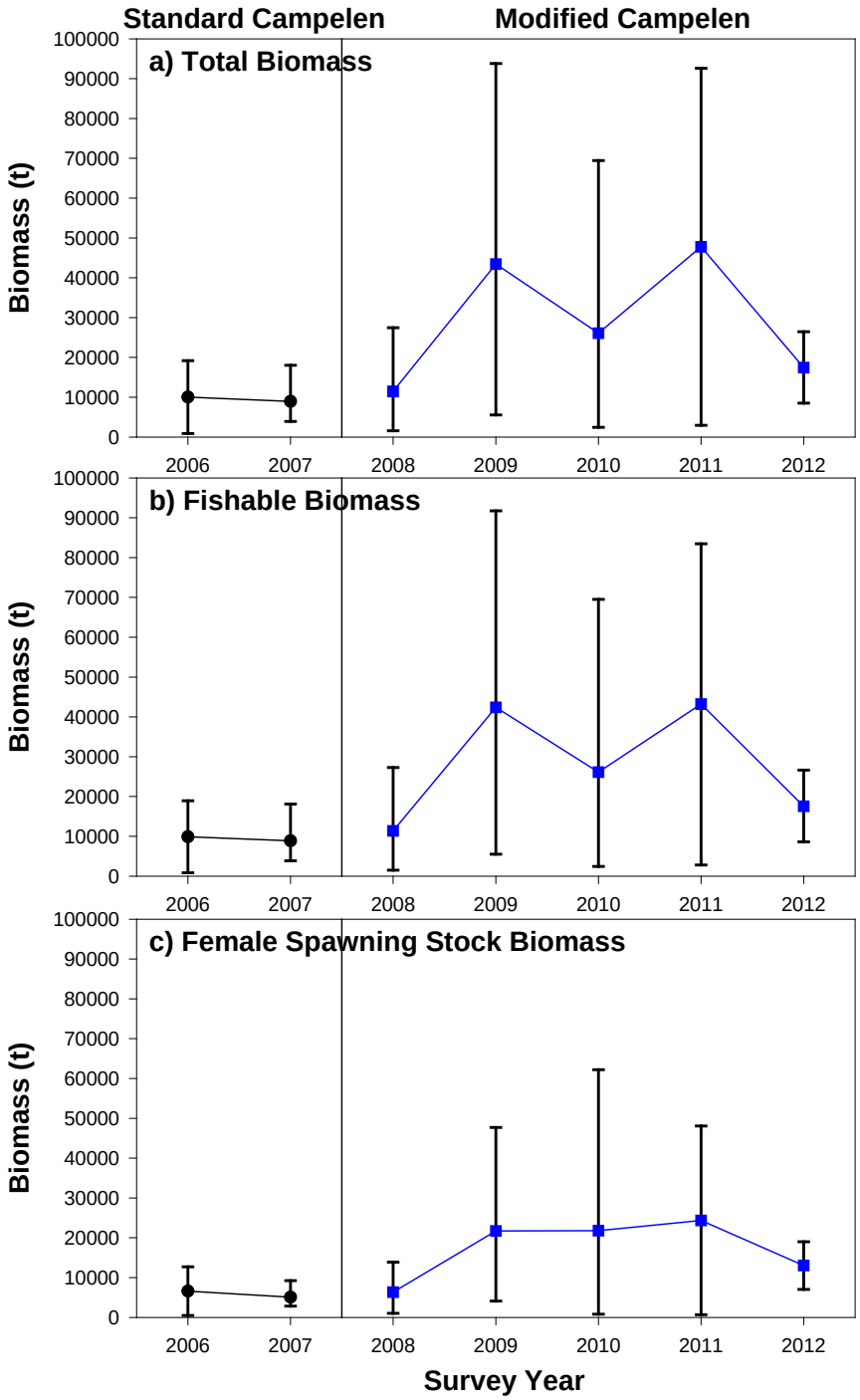

Figure 10. Total, fishable and female spawning stock biomass indices of Pandalus borealis *in the RISA-East survey areas for the years 2006-2012. Note the change to the modified Campelen trawl.*

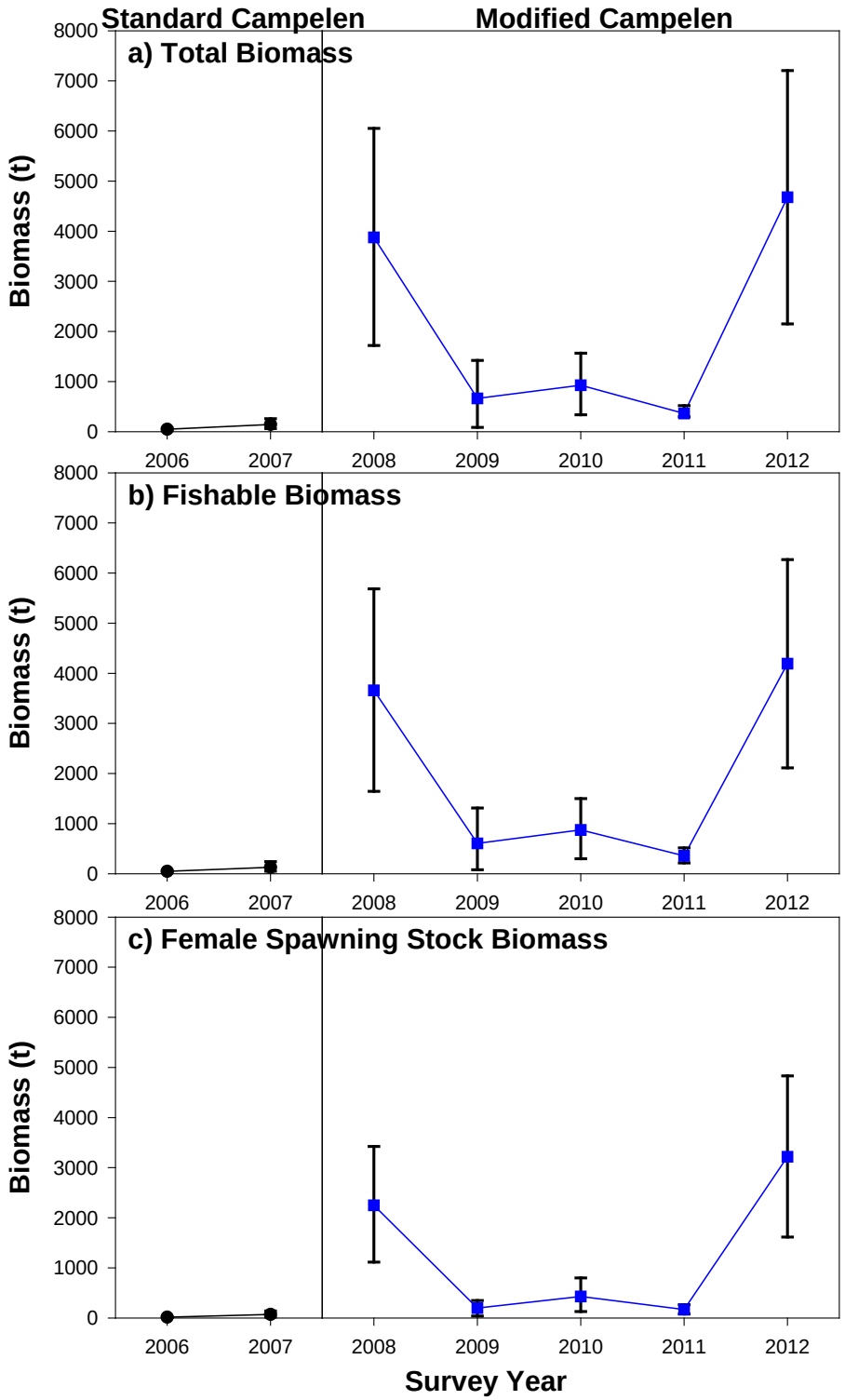

Figure 11. Total, fishable and female spawning stock biomass indices of Pandalus borealis *in the RISA-West survey areas for the years 2006-2012. Note the change to the modified Campelen trawl.*

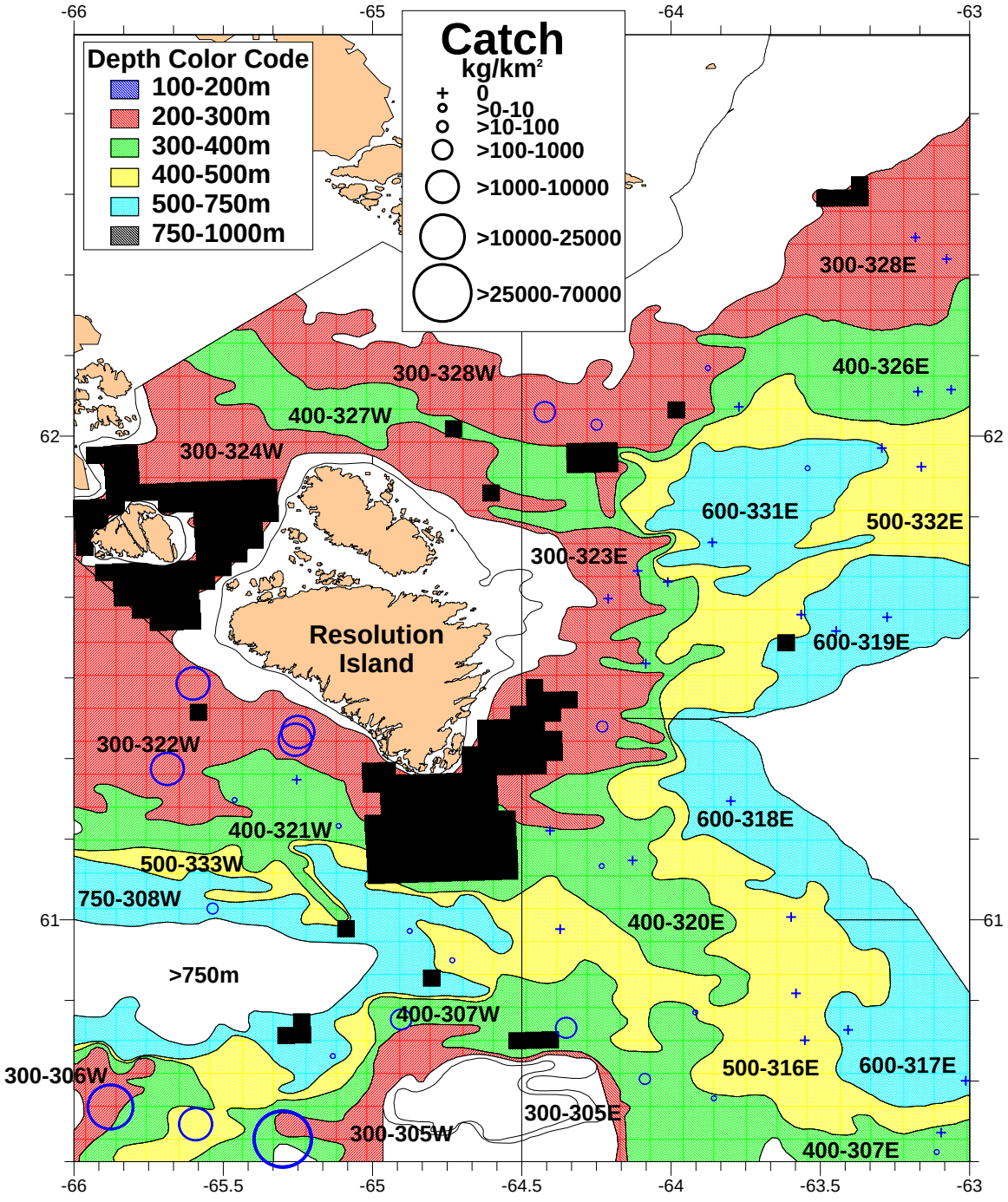

Figure 12. Standardized Pandalus montagui *catch from the RISA survey areas in 2012 overlying the depth contours and strata of the survey area. Blackened areas are cells removed from the survey design because of untrawlable bottom.*

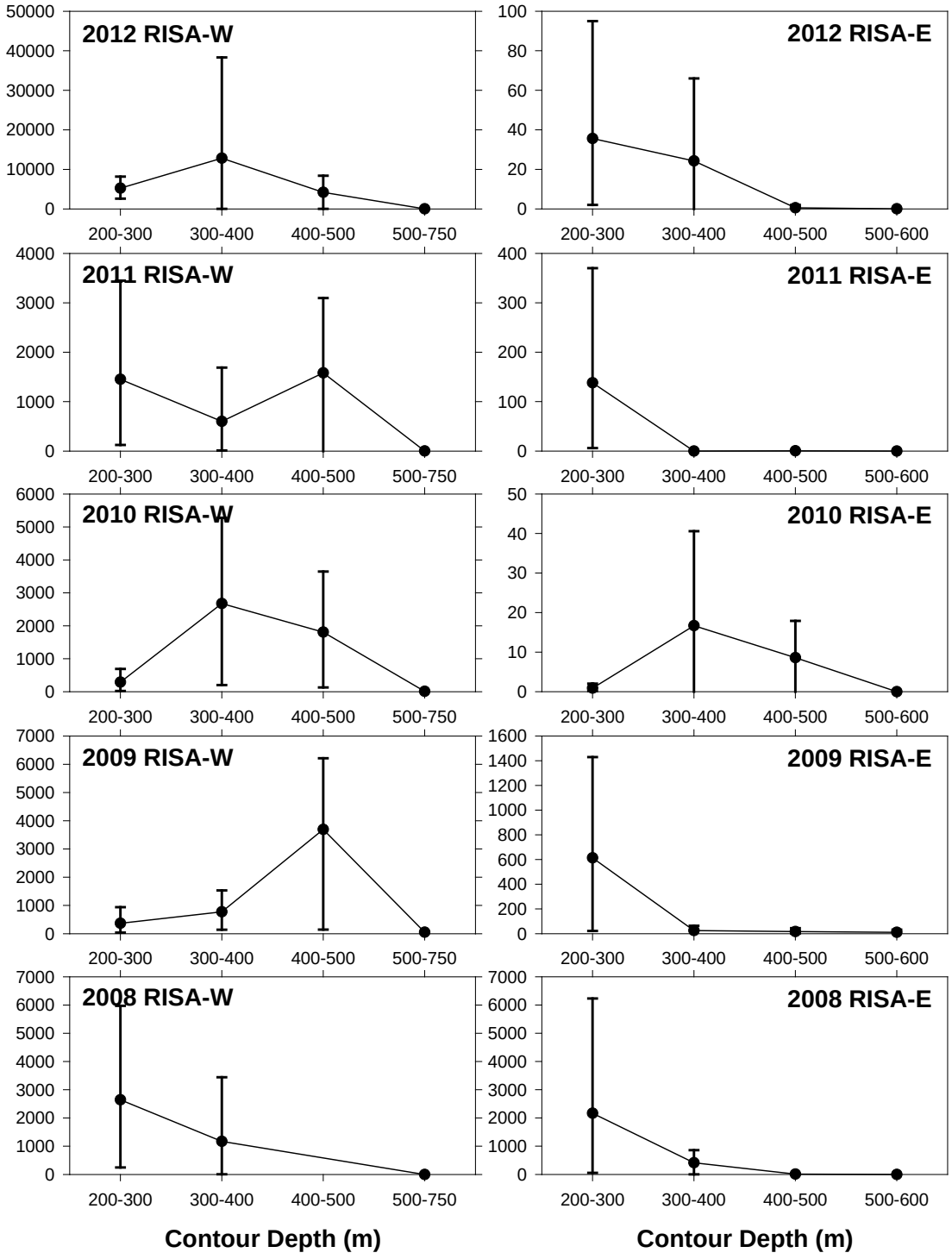

Figure 13. Mean Pandalus montagui *catch by depth contours in the RISA-East and RISA-West segments of the Eastern Assessment Zone for the survey years 2008-2012.*

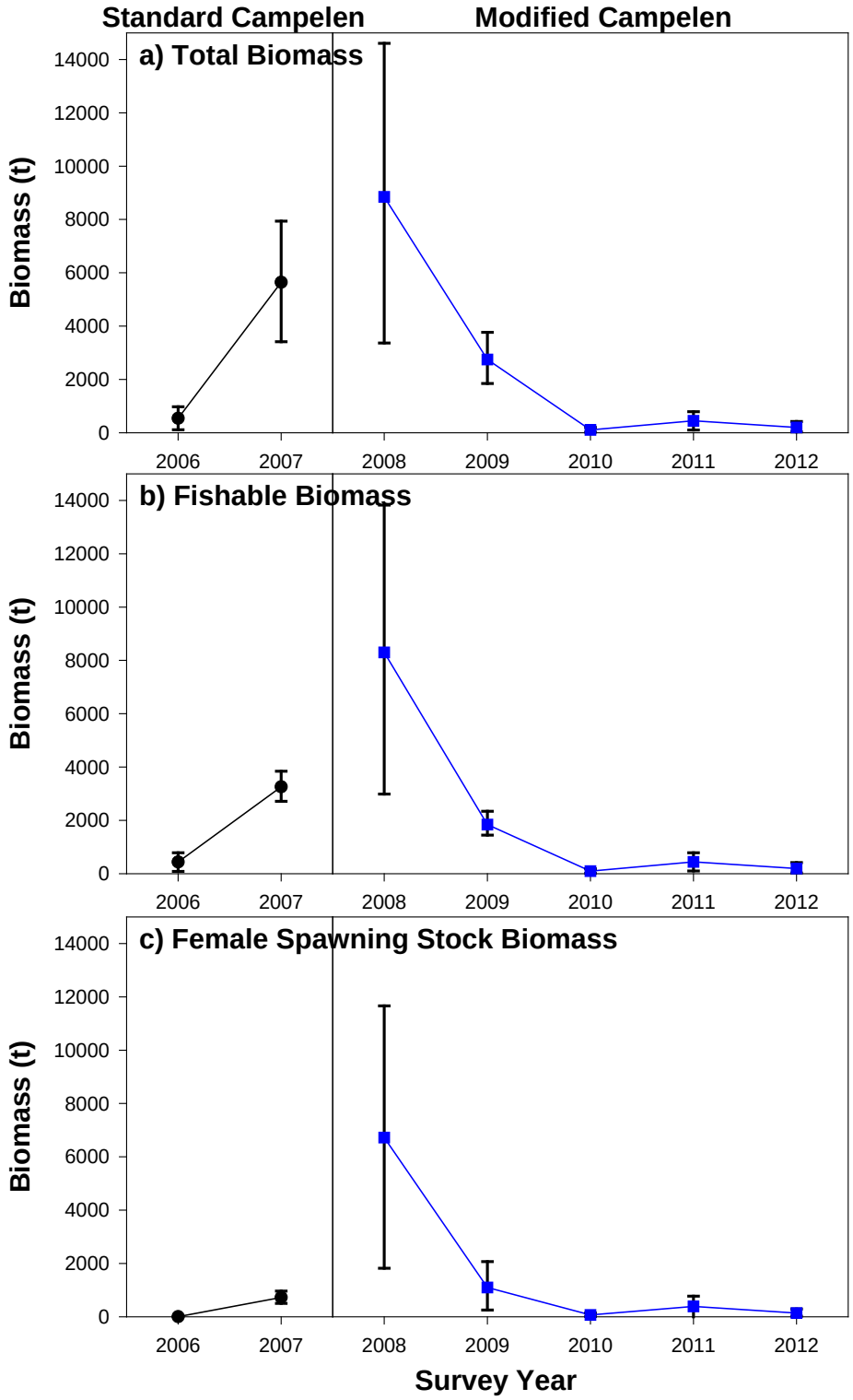

Figure 14. Total, fishable and female spawning stock biomass indices of Pandalus montagui *in the RISA-East survey areas for the years 2006-2012. Note the change to the modified Campelen trawl.*

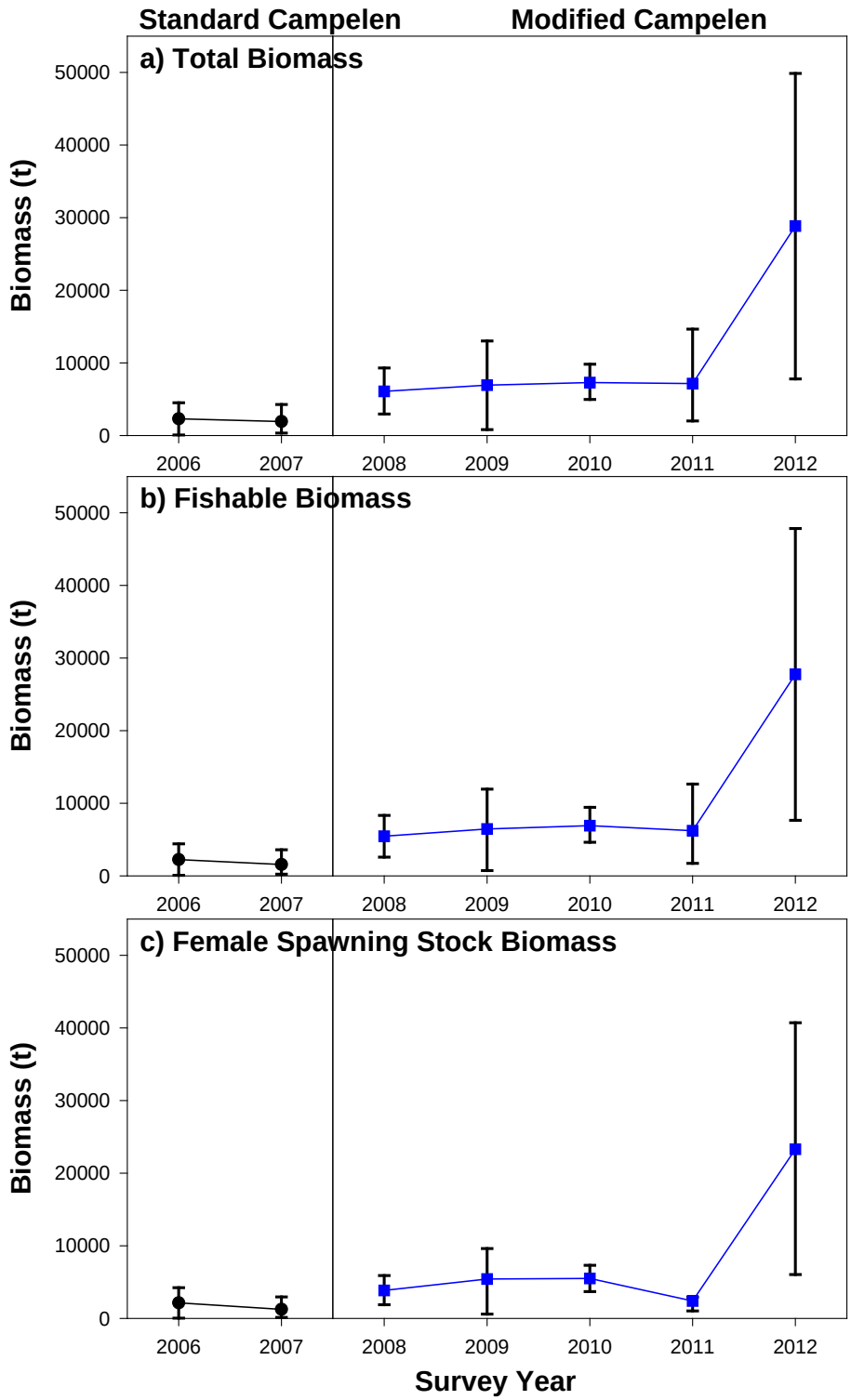

Figure 15. Total, fishable and female spawning stock biomass indices of Pandalus montagui *in the RISA-West survey areas for the years 2006-2012. Note the change to the modified Campelen trawl.*

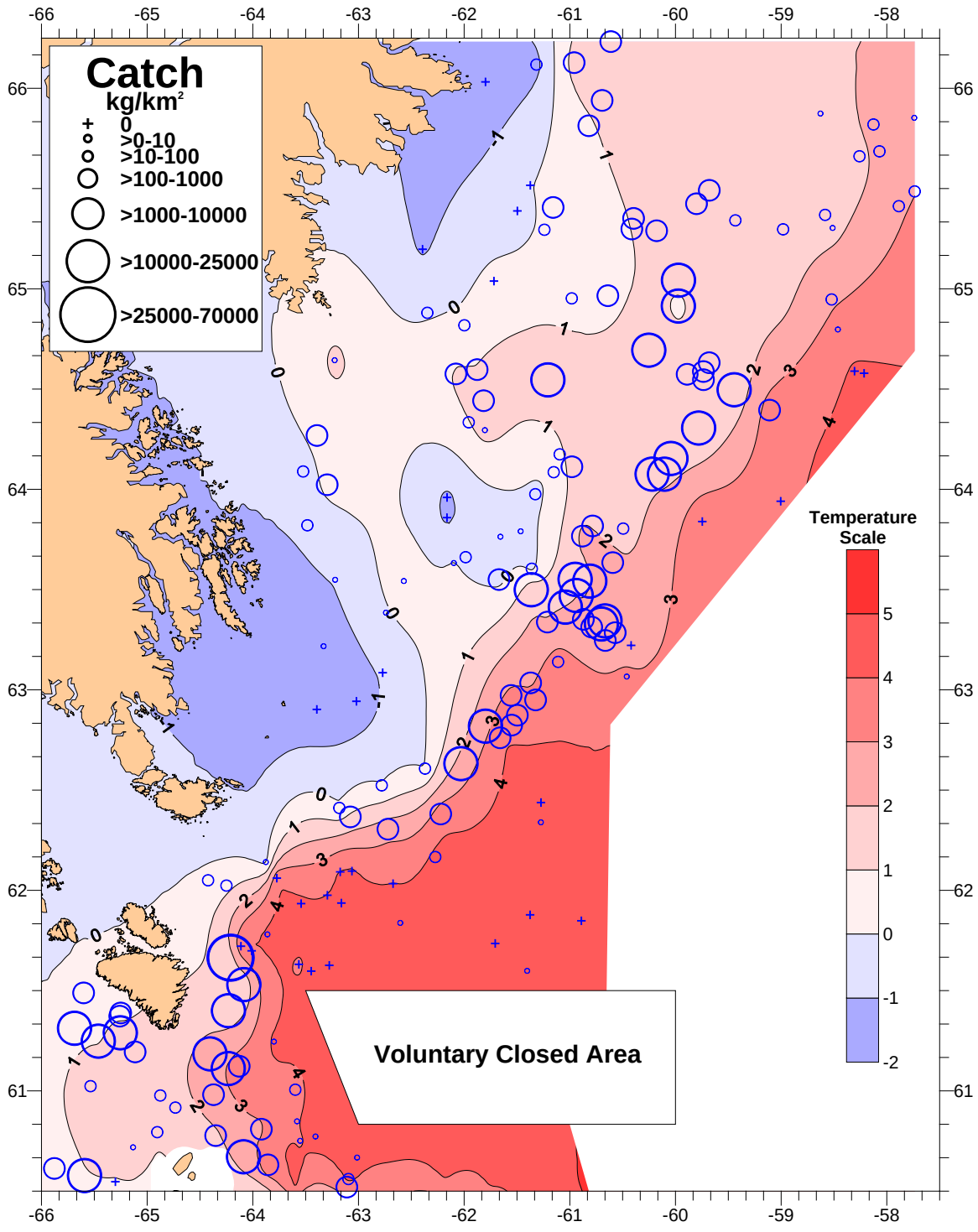

Figure 16. Standardized Pandalus borealis *catch from the 2012 NSRF-DFO Assessment Zone (SFA2EX and RISA) survey overlying the temperature contours observed in the study area.*

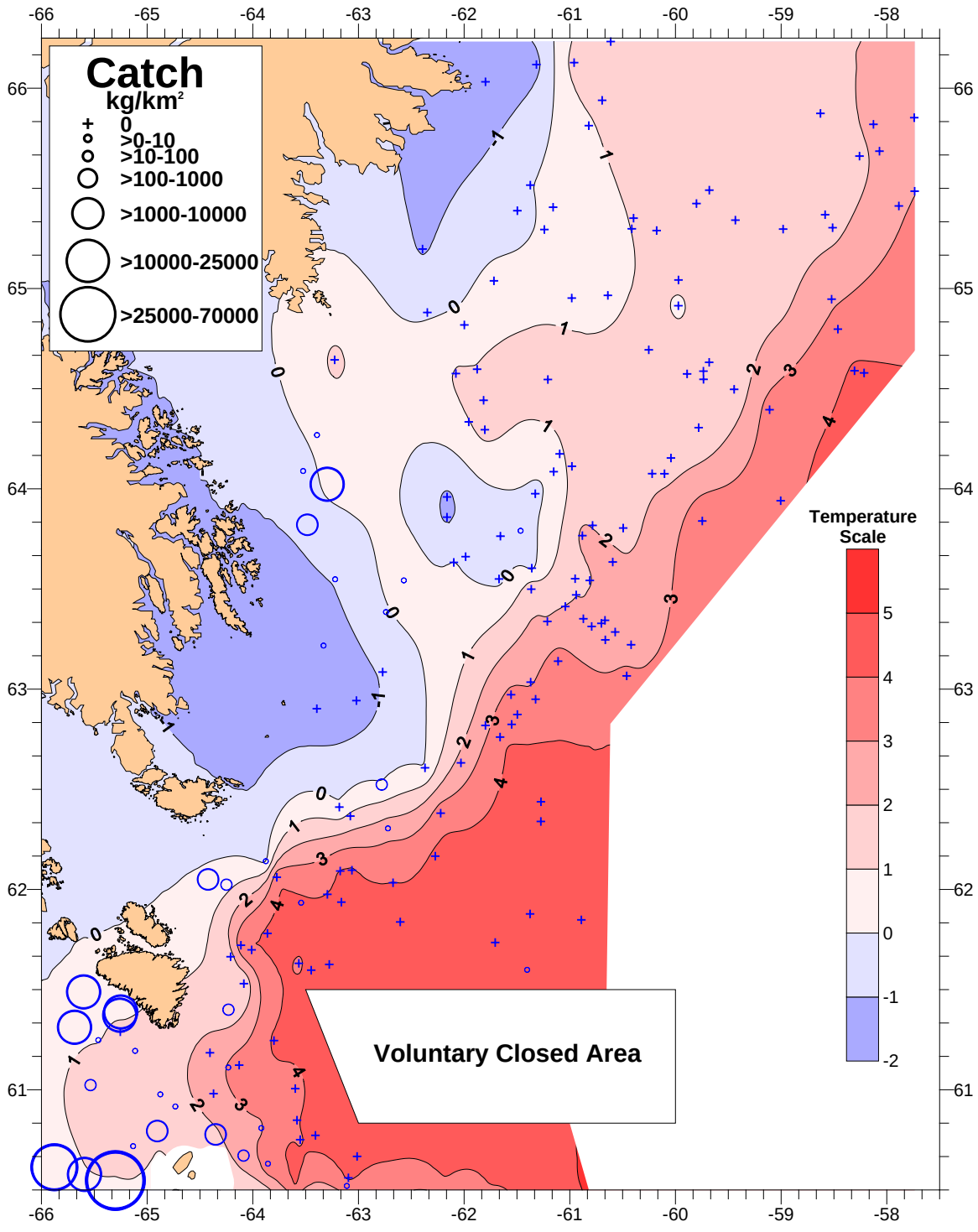

Figure 17. Standardized Pandalus montagui *catch from the 2012 Eastern Assessment Zone survey overlying the temperature contours observed in the study area.*

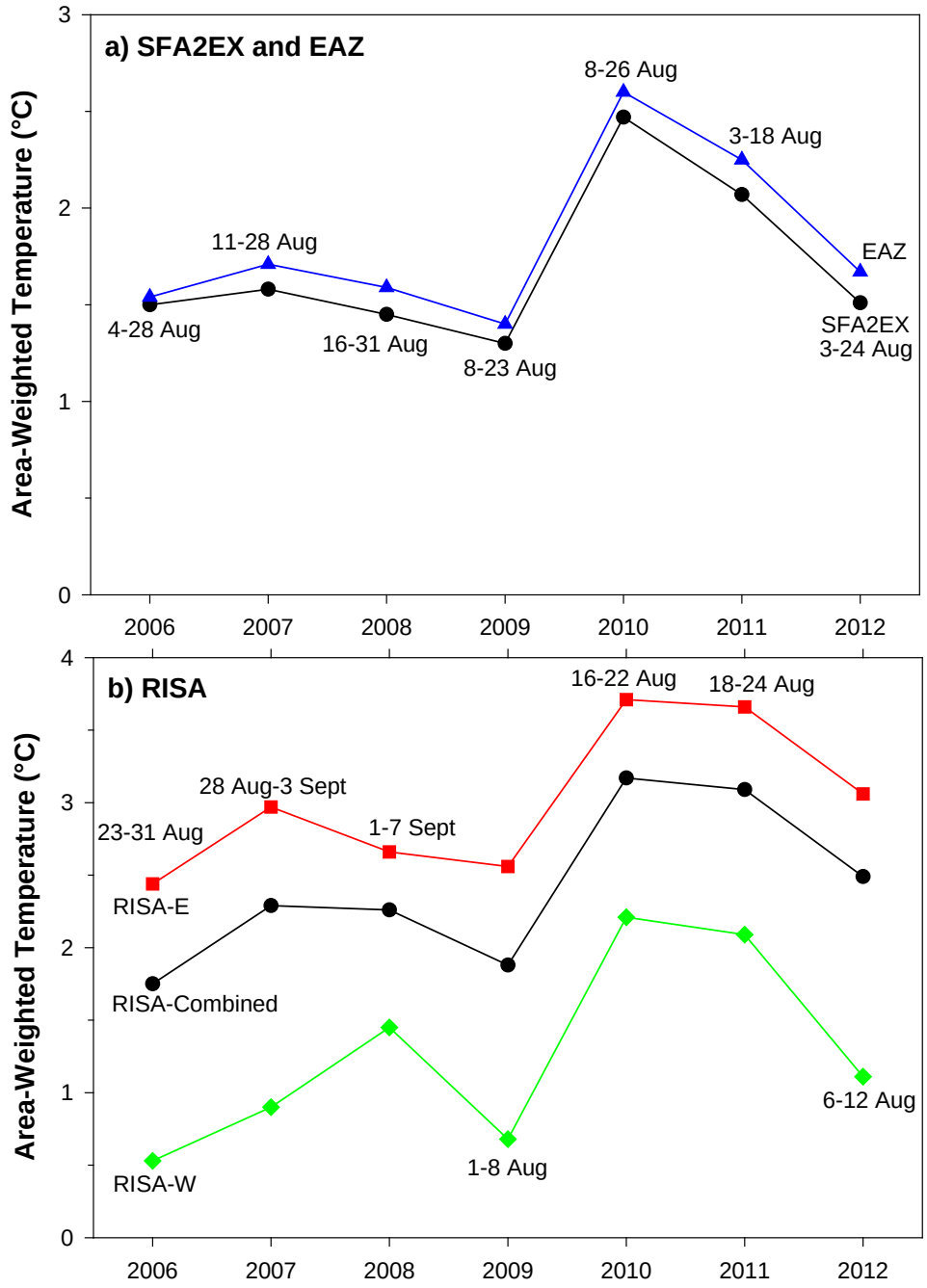

Figure 18. Mean area-weighted bottom temperatures in the Eastern Assessment Zone for a) SFA2EX (black circle) and EAZ (blue triangle) and b) RISA showing RISA combined (black circle), RISA-E (red square) and RISA-W (green diamond) for the 2006-2012 surveys. Point label indicate the dates over which samples were taken.

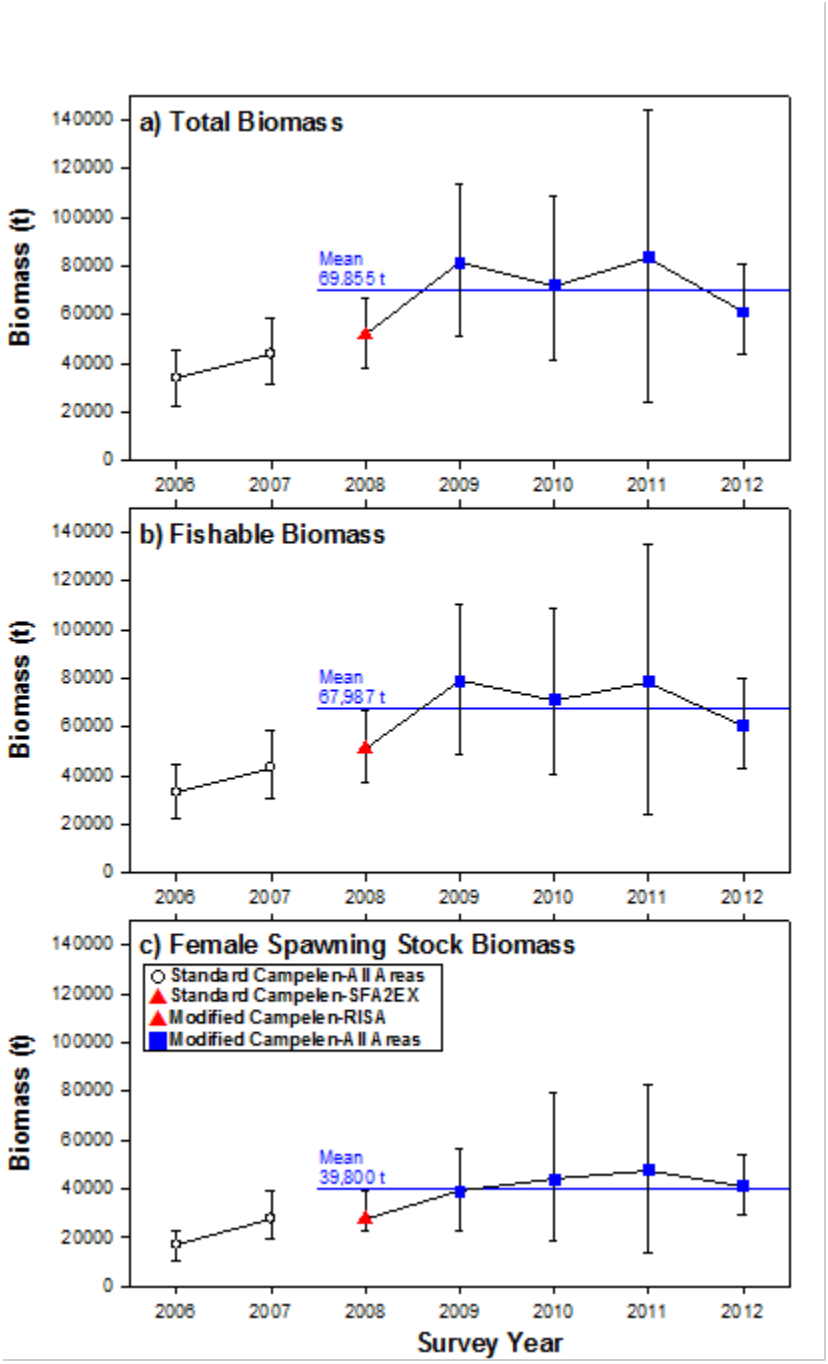

Figure 19. Total, fishable and female spawning stock biomass indices of Pandalus borealis *in the Eastern Assessment Zone for the survey years 2006-2012. Note the change to the modified Campelen trawl. See Table 1 for associated data.*

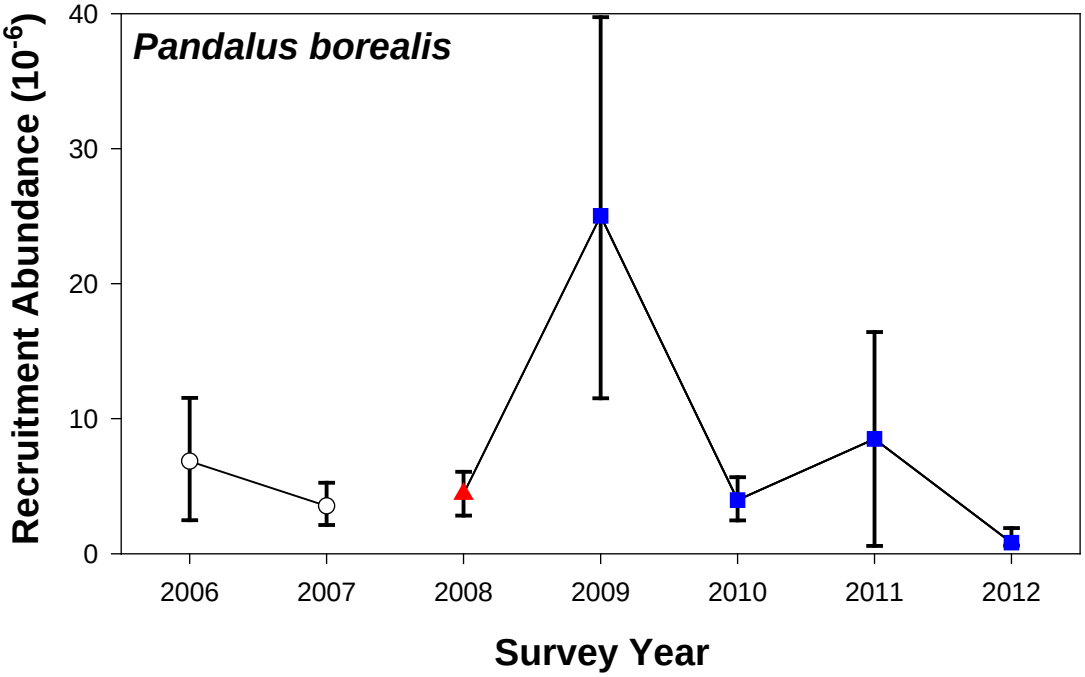

Figure 20. Recruitment index based on the Campelen cod end collection of Pandalus borealis *11.5-17.0 mm carapace length in the NSRF-DFO Assessment Zone for the survey years 2006-2012.*

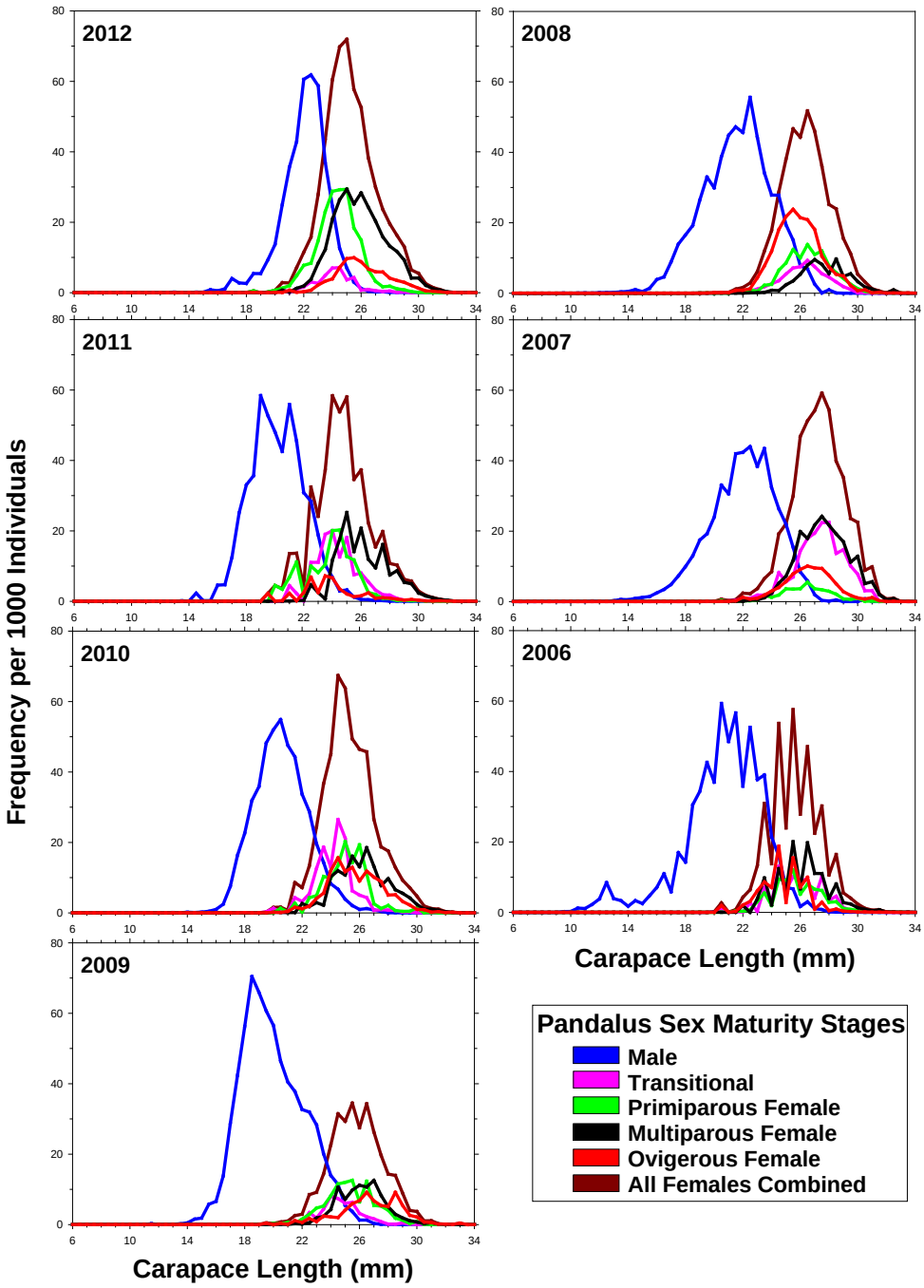

Figure 21. Length frequency curves for all sex maturities of Pandalus borealis *collected in the Campelen cod end in the Eastern Assessment Zone over the survey years 2006-2012.*

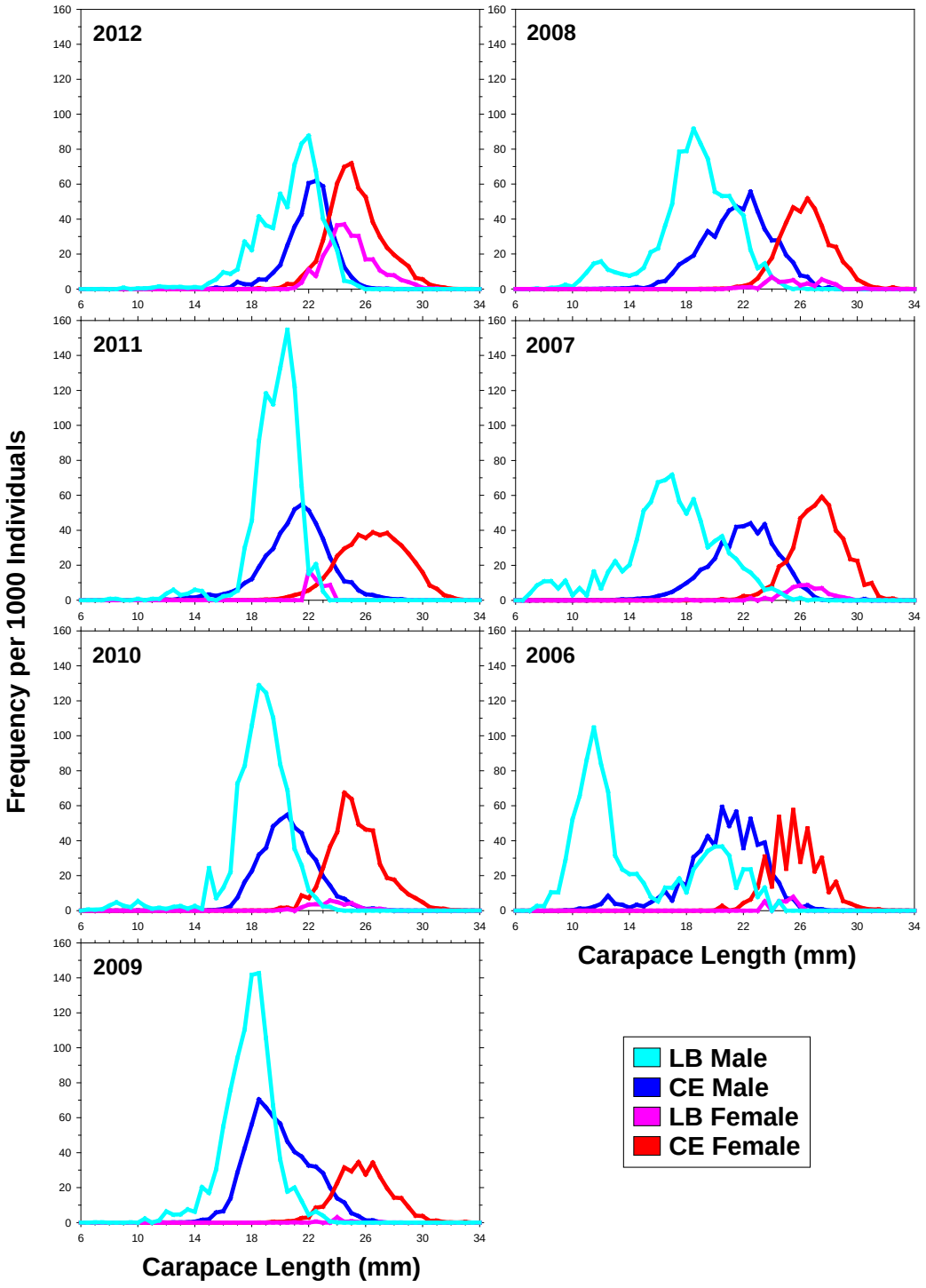

Figure 22. Overall length frequency distributions of male and female Pandalus borealis *in the Eastern Assessment Zone as captured in the cod end (CE) and Linney Bag (LB).*

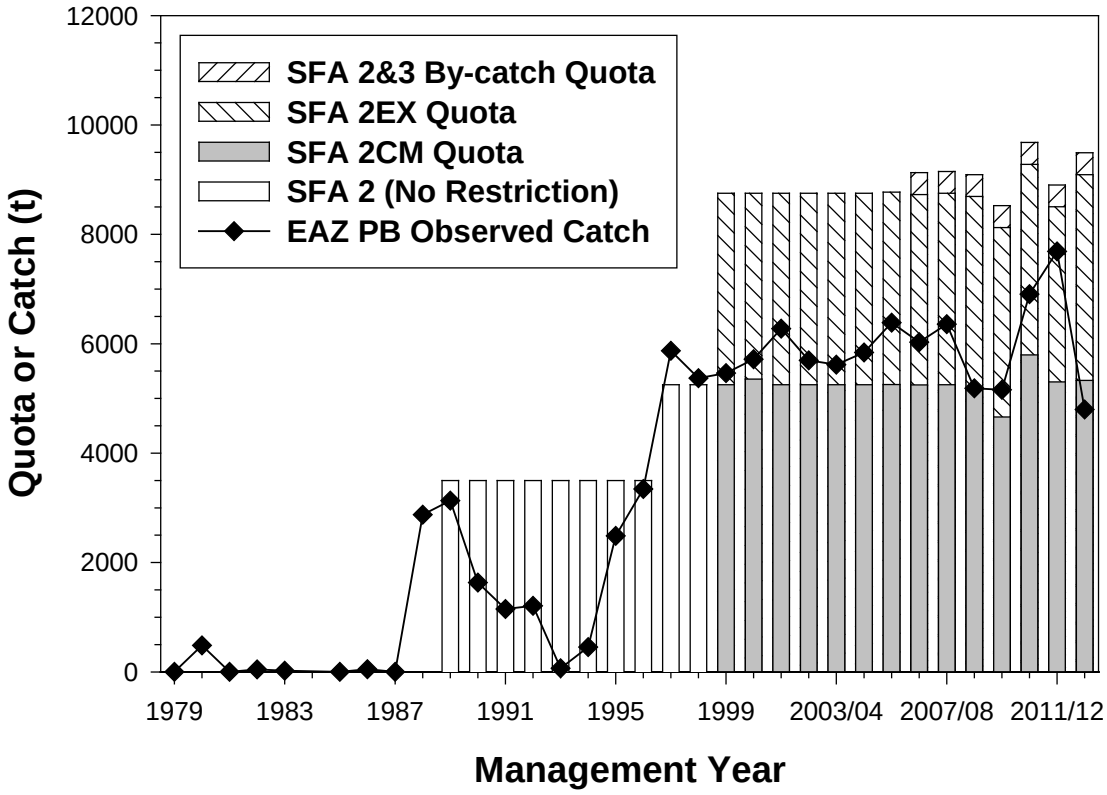

Figure 23. Eastern Assessment Zone Pandalus borealis *TAC and catch recorded by the observer program. Observer catch records may be incomplete for 2012/13. See Table 3 for associated data.*

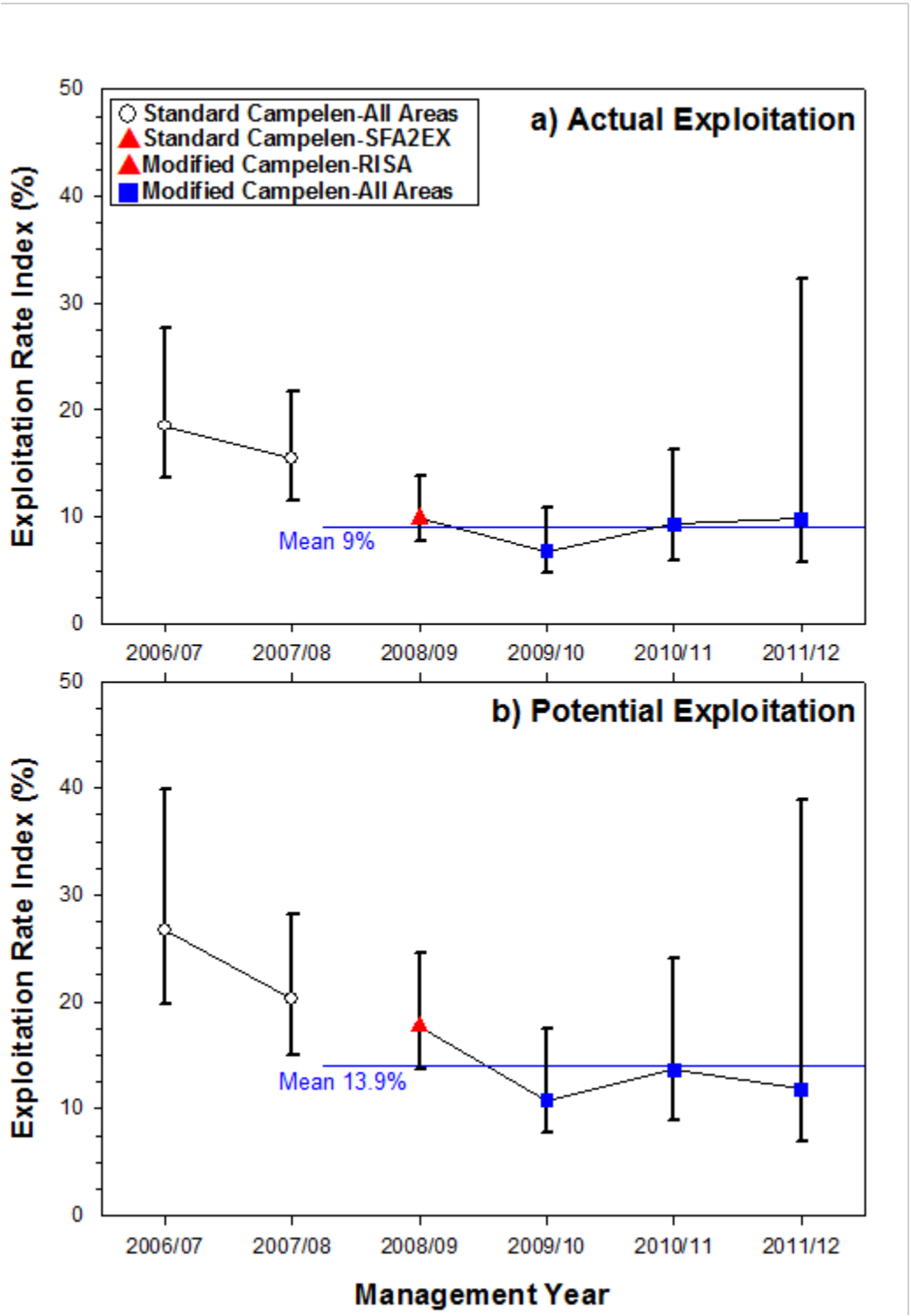

Figure 24. Pandalus borealis Eastern Assessment Zone exploitation rate indices for the a) reported rate, based on the catch taken and the b) potential rate if the entire TAC assigned to the Eastern Assessment Zone was taken.

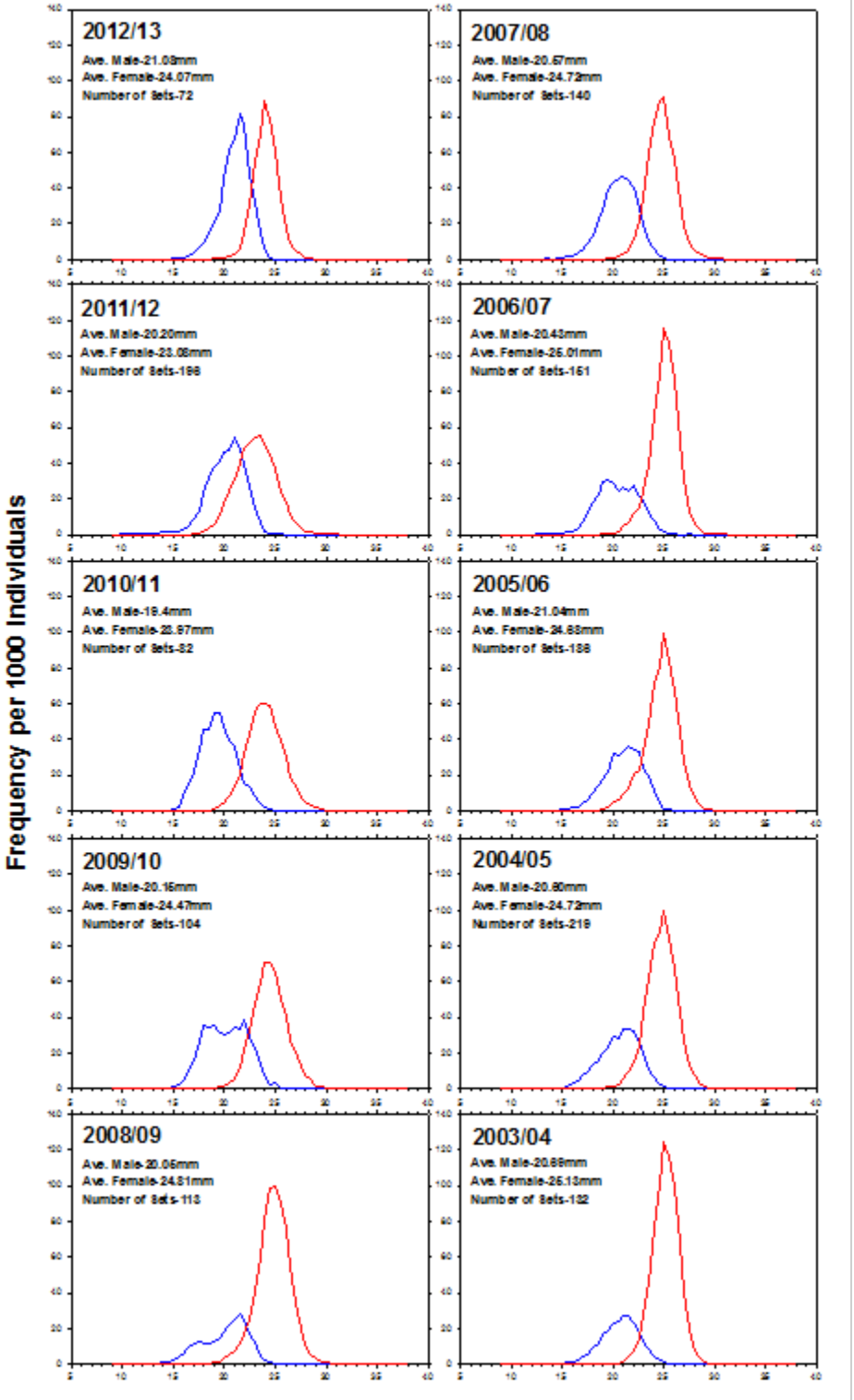

Figure 25. Length frequency of the commercial catch of male (blue) and female (red) Pandalus borealis *in the Eastern Assessment Zone over the past decade, management years 2003/04 through 2012/13.*

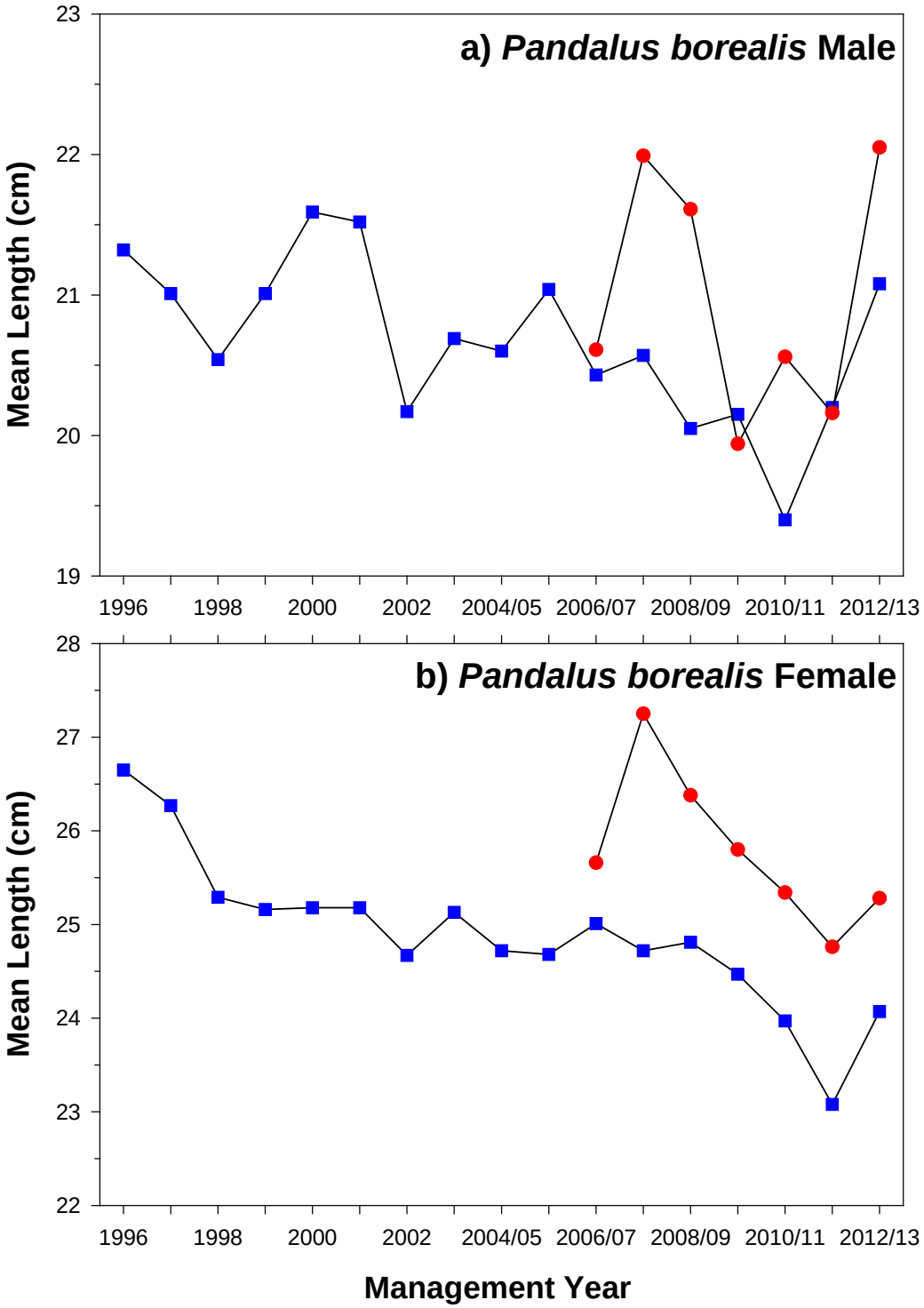

Figure 26. Mean length indices for a) male and b) female Pandalus borea*lis caught in the fishery (blue square) and survey (red circle) in the Eastern Assessment Zone for the 1996 to 2012/13 management years.*

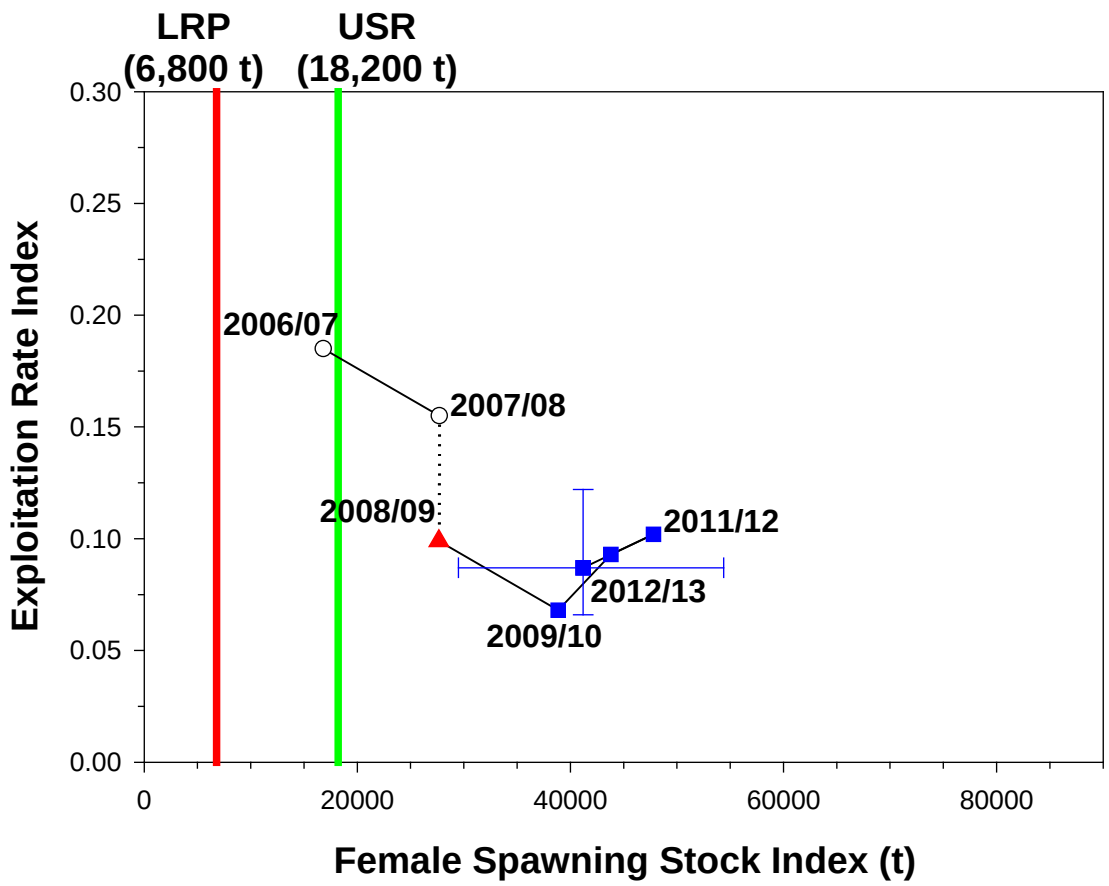

Figure 27. Eastern Assessment Zone trajectory of Pandalus borealis female spawning stock and exploitation rate in reference to provisional limit reference points calculated using the proxy developed at two CSAS workshops in 2009. USR=Upper stock reference and LRP=limit reference point referring to 80% and 30% respectively of the geometric mean of the female spawning stock biomass indices from the 2006-2008 surveys.

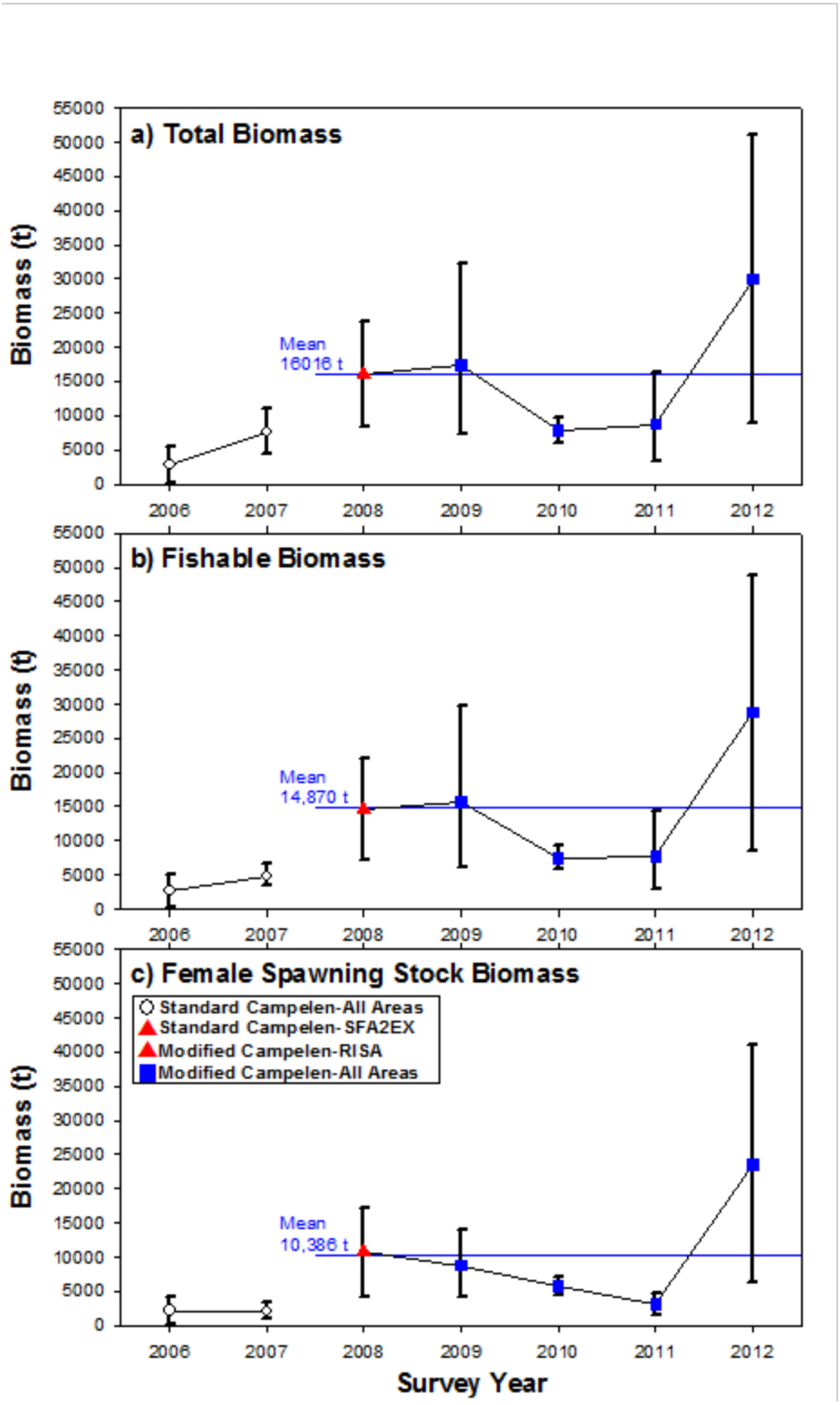

Figure 28. a) Total, b) fishable and c) female spawning stock biomass indices of Pandalus montagui *in the Eastern Assessment Zone for the survey years 2006-2012. Note the change to the modified Campelen trawl. See Table 2 for associated data.*

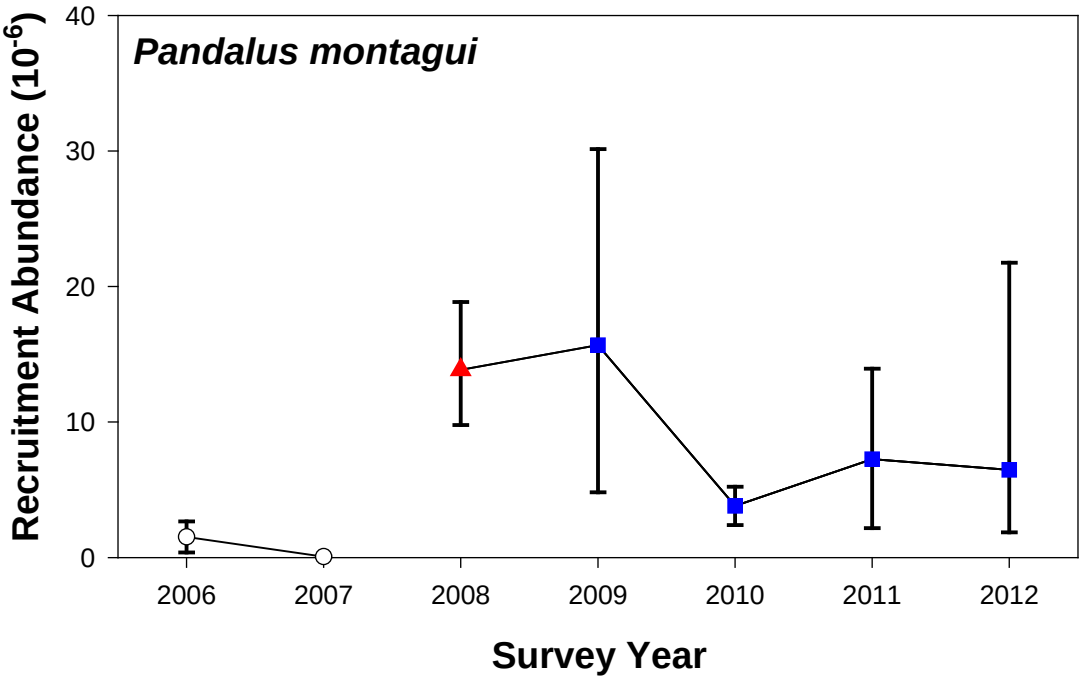

Figure 29. Recruitment index based on the Campelen cod end collection of Pandalus montagui *11.5-17.0 mm carapace length in the Eastern Assessment Zone for the survey years 2006-2012.*

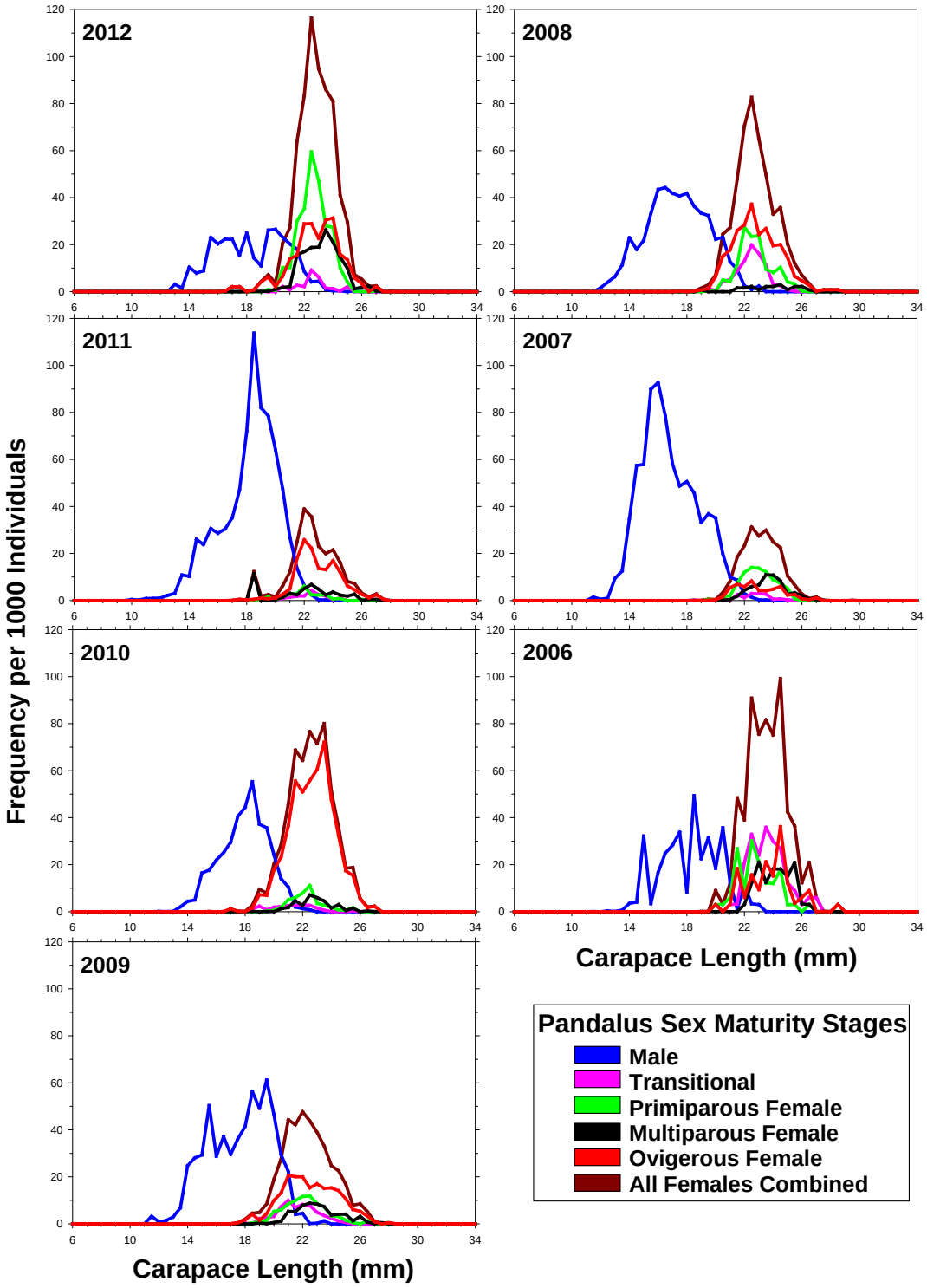

Figure 30. Length frequency curves for all sex maturities of Pandalus montagui *collected in the Campelen cod end in the Eastern Assessment Zone over the survey years 2006-2012.*

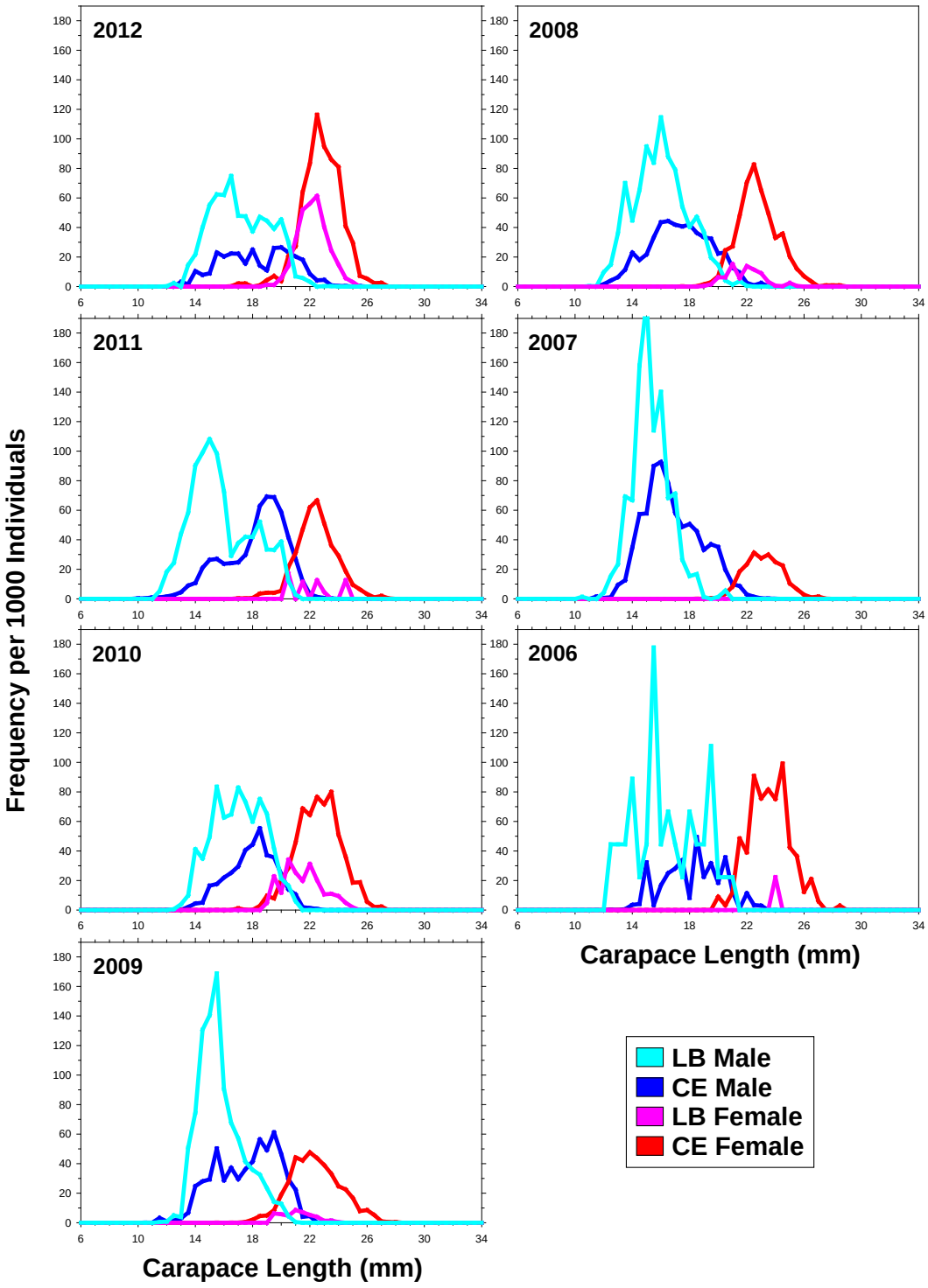

Figure 31. Overall length frequency distributions of male and female Pandalus montagui *in the Eastern Assessment Zone as captured in the cod end (CE) and Linney Bag (LB).*

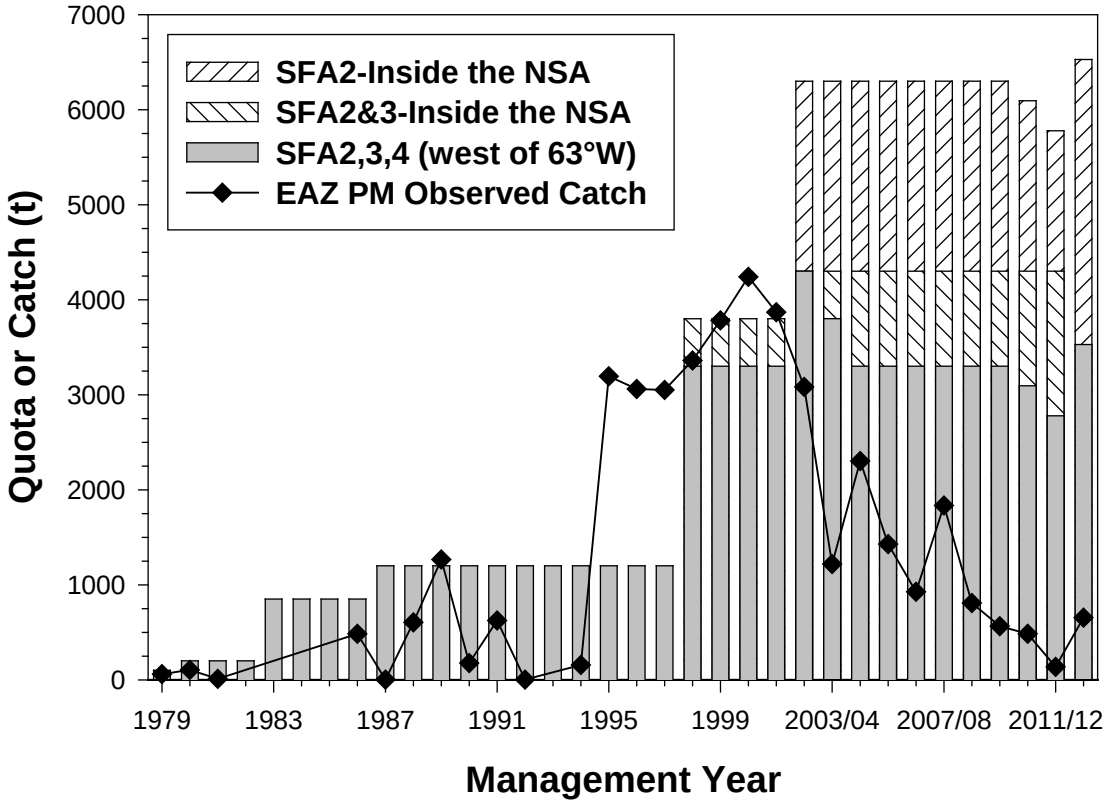

Figure 32. Eastern Assessment Zone Pandalus montagui *TAC and catch recorded by the observer program. Observer catch records may be incomplete for 2012/13. See Table 4 for associated data.*

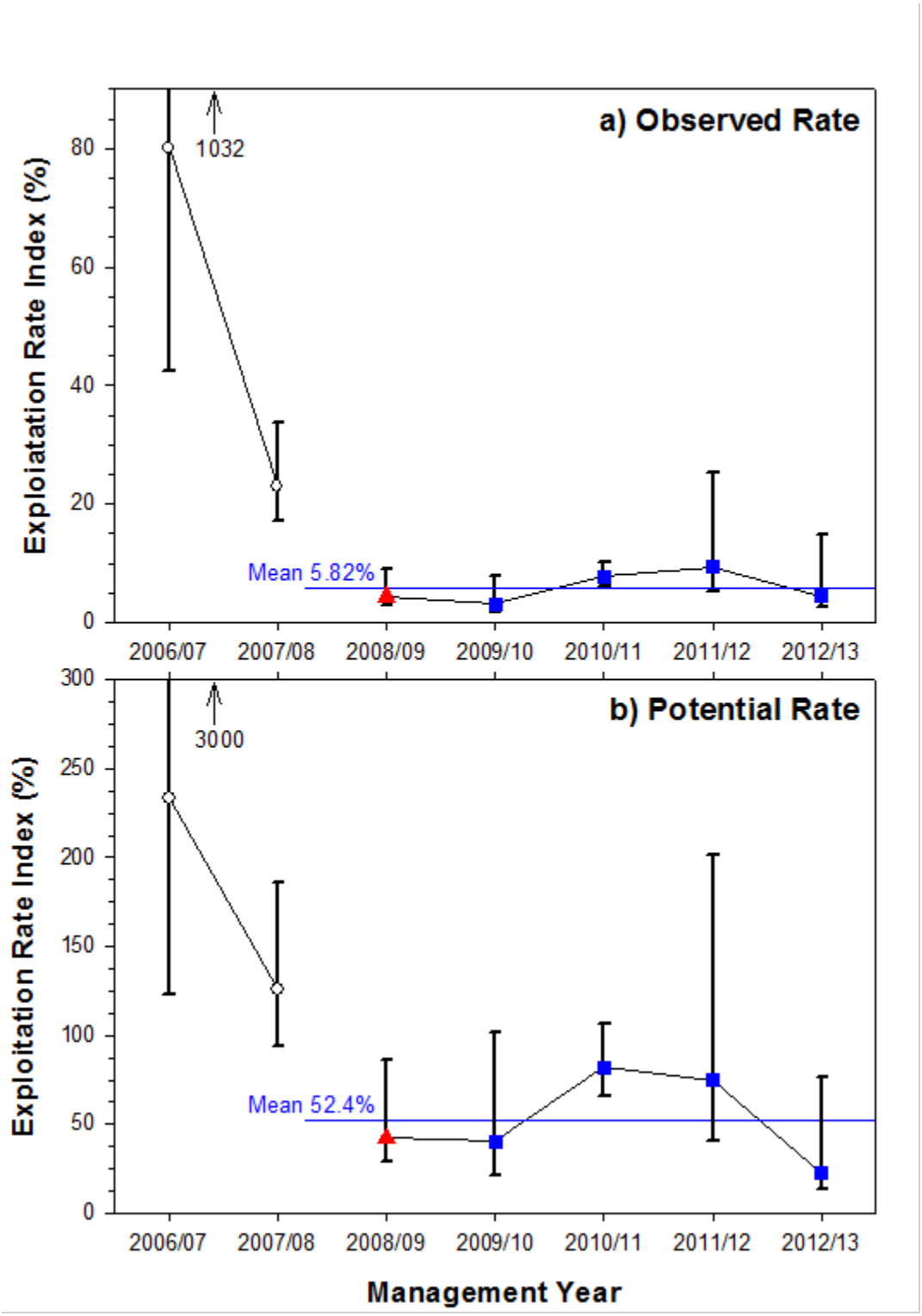

Figure 33. Pandalus montagui *Eastern Assessment Zone exploitation rate indices for the a) reported rate, based on the catch taken and the b) potential rate if the entire TAC assigned to the Eastern Assessment Zone was taken*

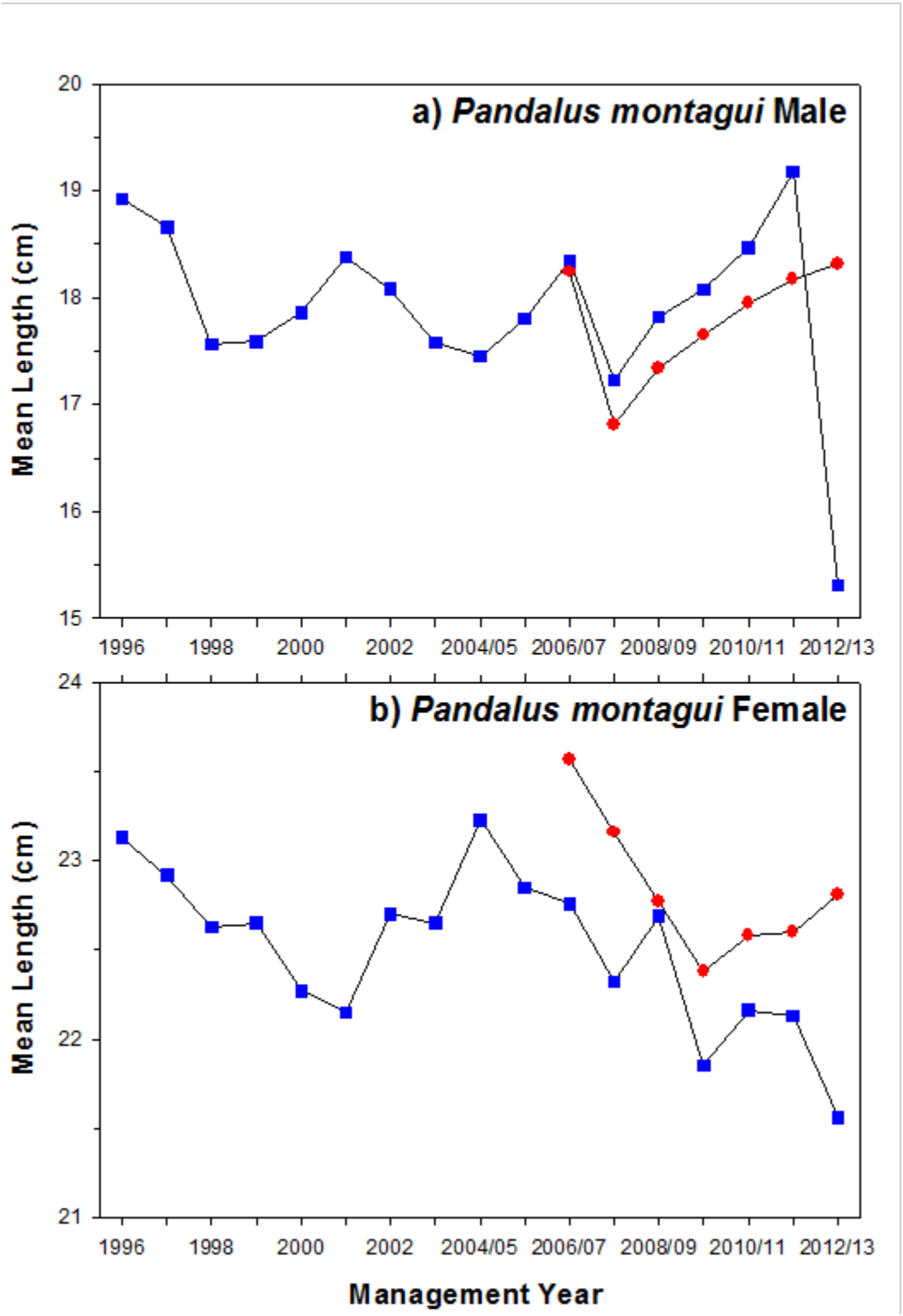

Figure 34. Mean length indices for a) male and b) female Pandalus montagui *caught in the fishery (blue square) and survey (red circle) in the Eastern Assessment Zone for the 1996 to 2012/13 management years.*

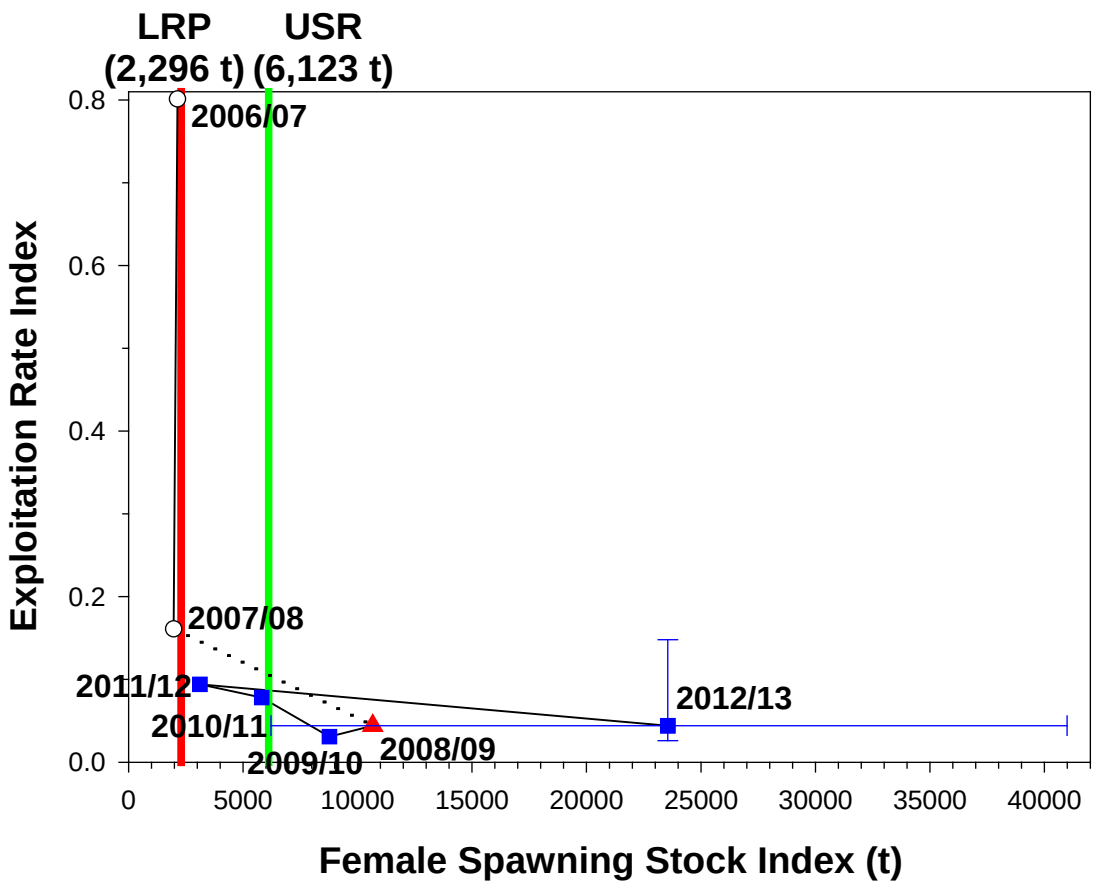

Figure 35. Eastern Assessment Zone trajectory of Pandalus montagui *female spawning stock and exploitation rate in reference to provisional limit reference points calculated using the proxy developed at two CSAS workshops in 2009. USR=Upper stock reference and LRP=limit reference point referring to 80% and 30% respectively of the geometric mean of the female spawning stock biomass indices from the 2006-2008 surveys.*

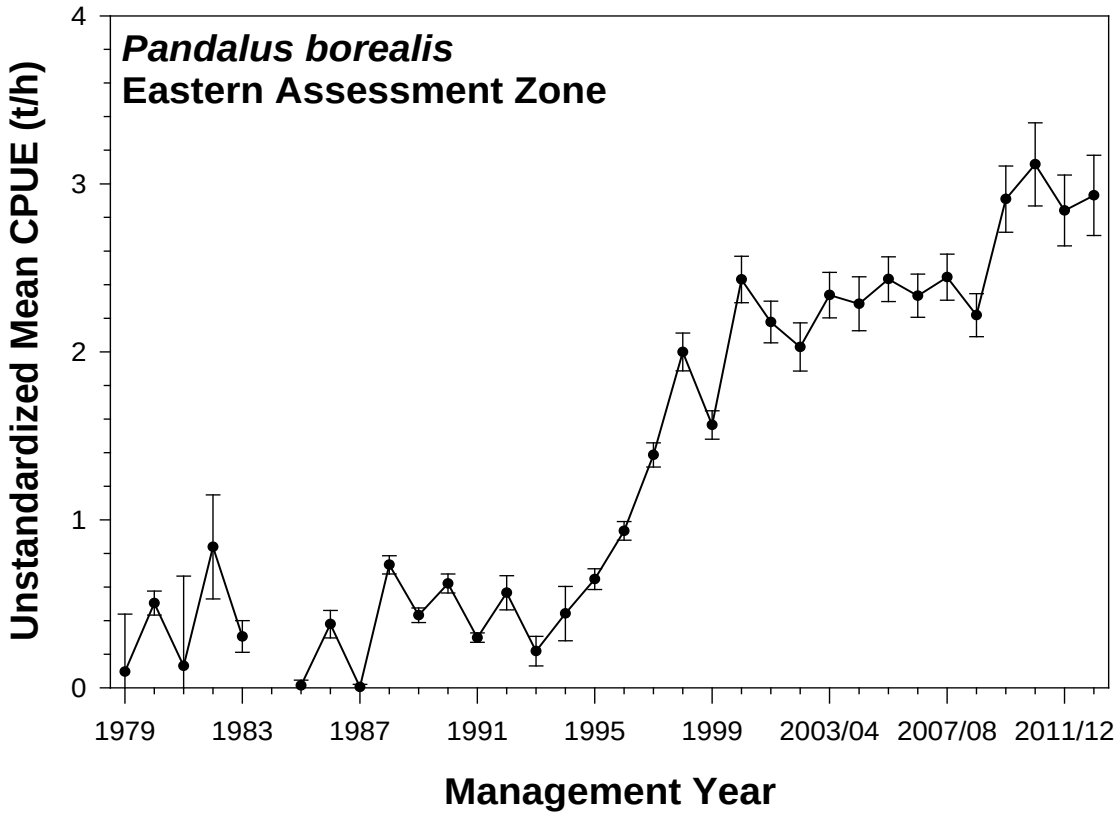

Figure 36. Unstandardized CPUE index for directed Pandalus borealis *fishing in the Eastern Assessment Zone. Observer records for 2012/13 season may be incomplete.*

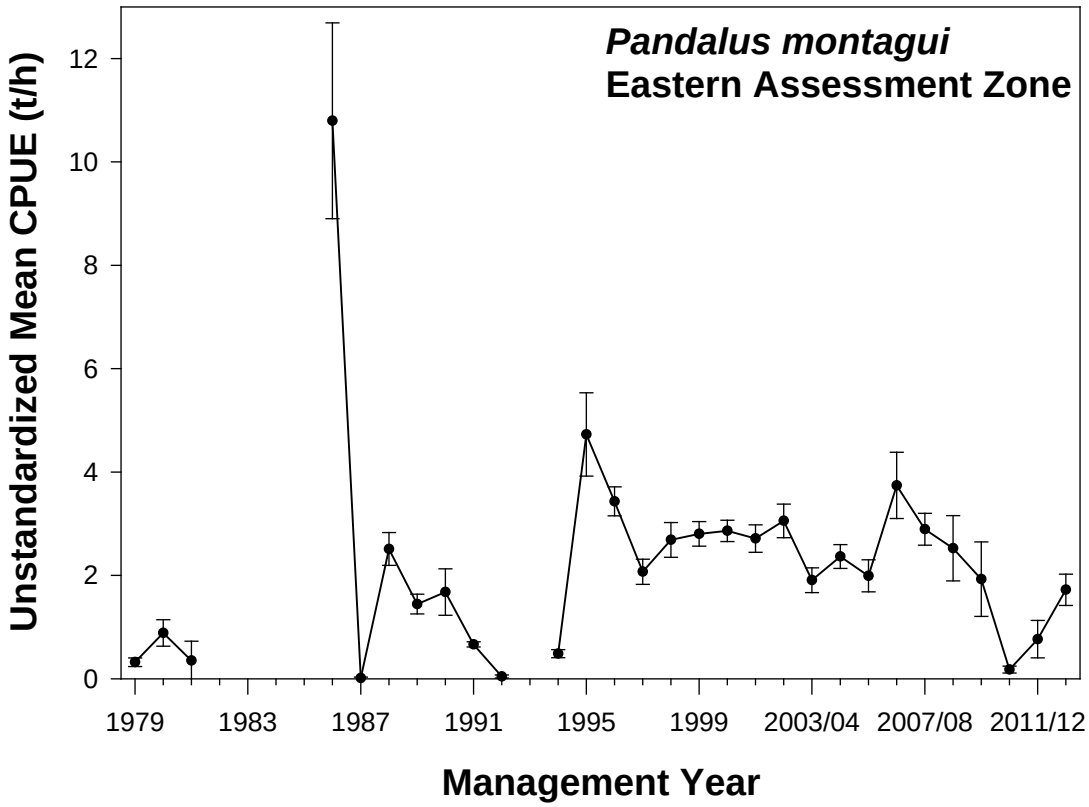

Figure 37. Unstandardized CPUE index for directed Pandalus montagui *fishing in the Eastern Assessment Zone. Observer records for 2012/13 season may be incomplete.*

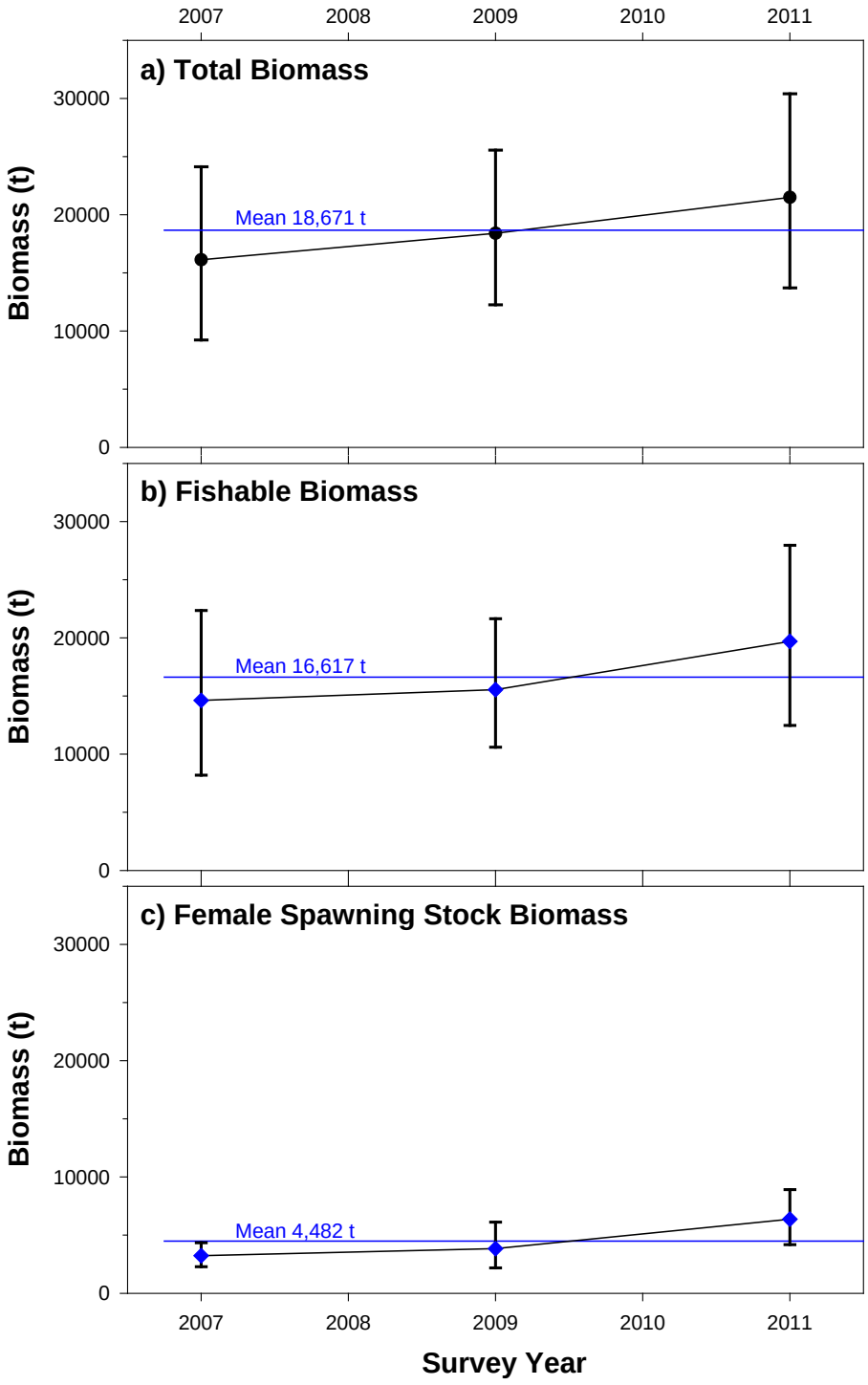

Figure 38. Total, fishable and female spawning stock biomass indices of Pandalus borealis *in the Western Assessment Zone for the years 2007, 2009 and 2011. See Table 5 for associated data.*

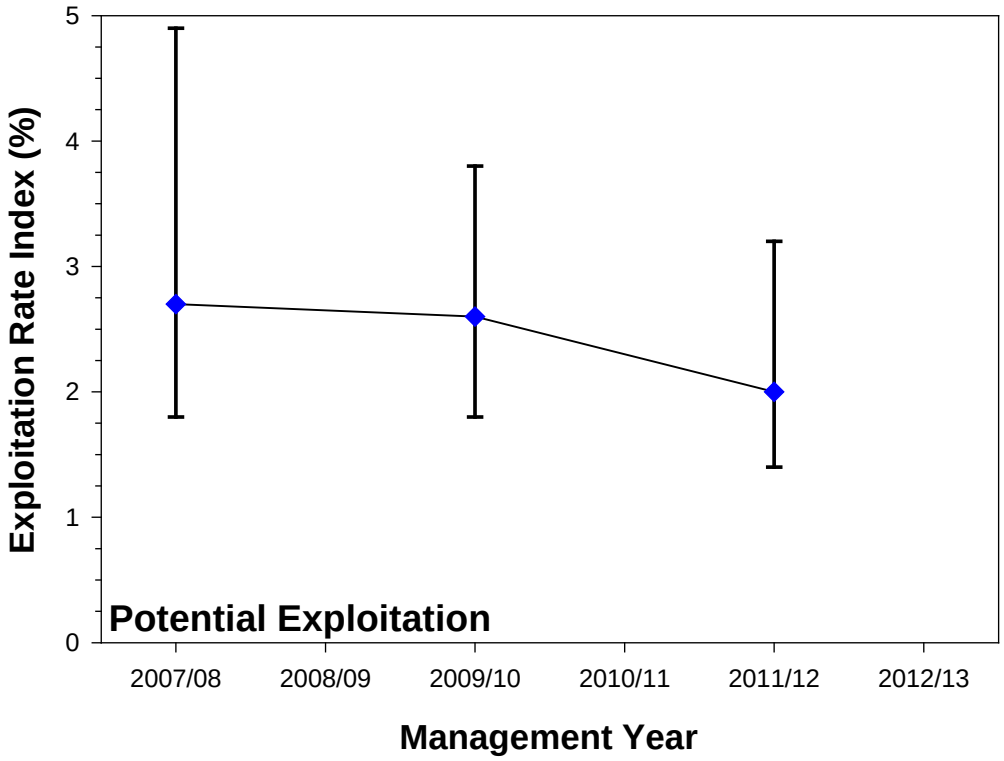

Figure 39. Western Assessment Zone Pandalus borealis *potential exploitation rate index if the entire TAC assigned to the Eastern Assessment Zone was taken.*

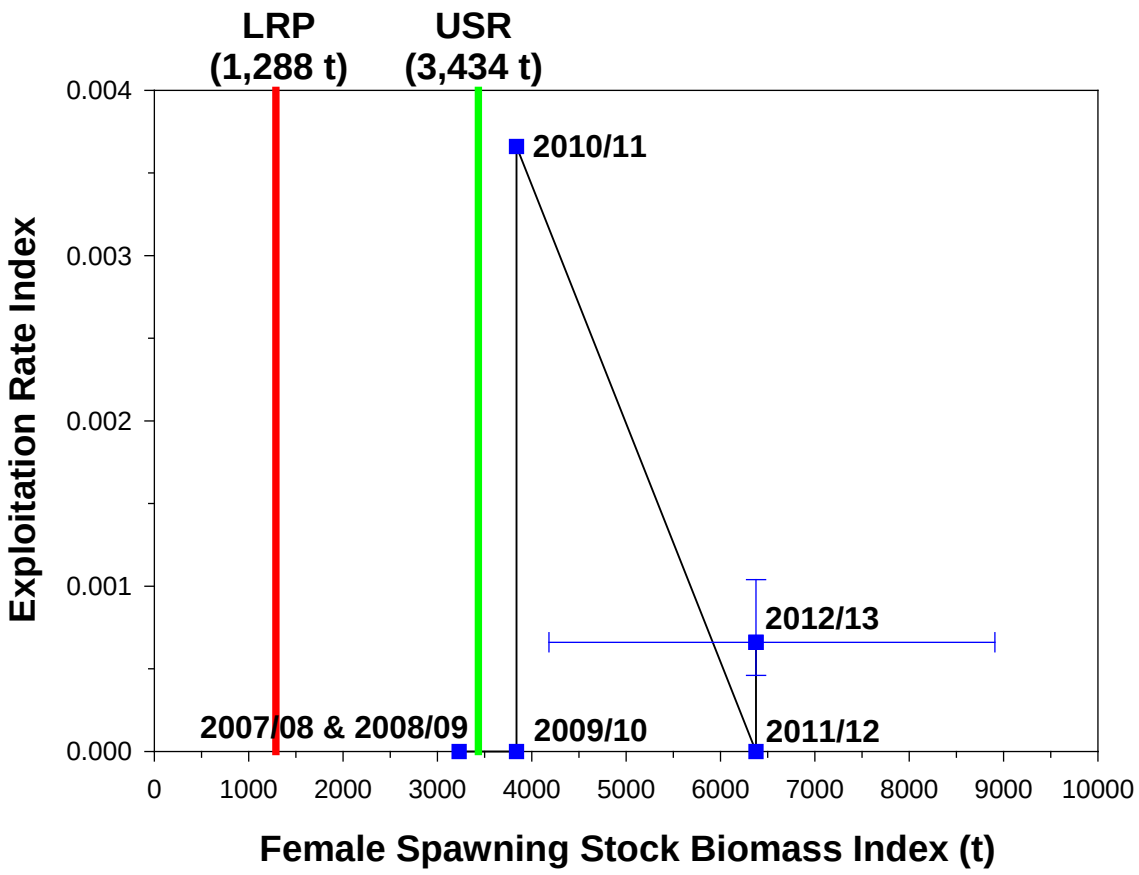

Figure 40. Western Assessment Zone trajectory of Pandalus borealis female spawning stock and exploitation rate in reference to provisional limit reference points calculated using the proxy developed at two CSAS workshops in 2009. USR=Upper stock reference and LRP=limit reference point referring to 80% and 30% respectively of the geometric mean of the female spawning stock biomass indices from the 2007, 2009, and 2011 surveys. Since the area is surveyed biennially, exploitation rates from years without a survey were calculated assuming the population had not changed from the survey conducted the previous year.

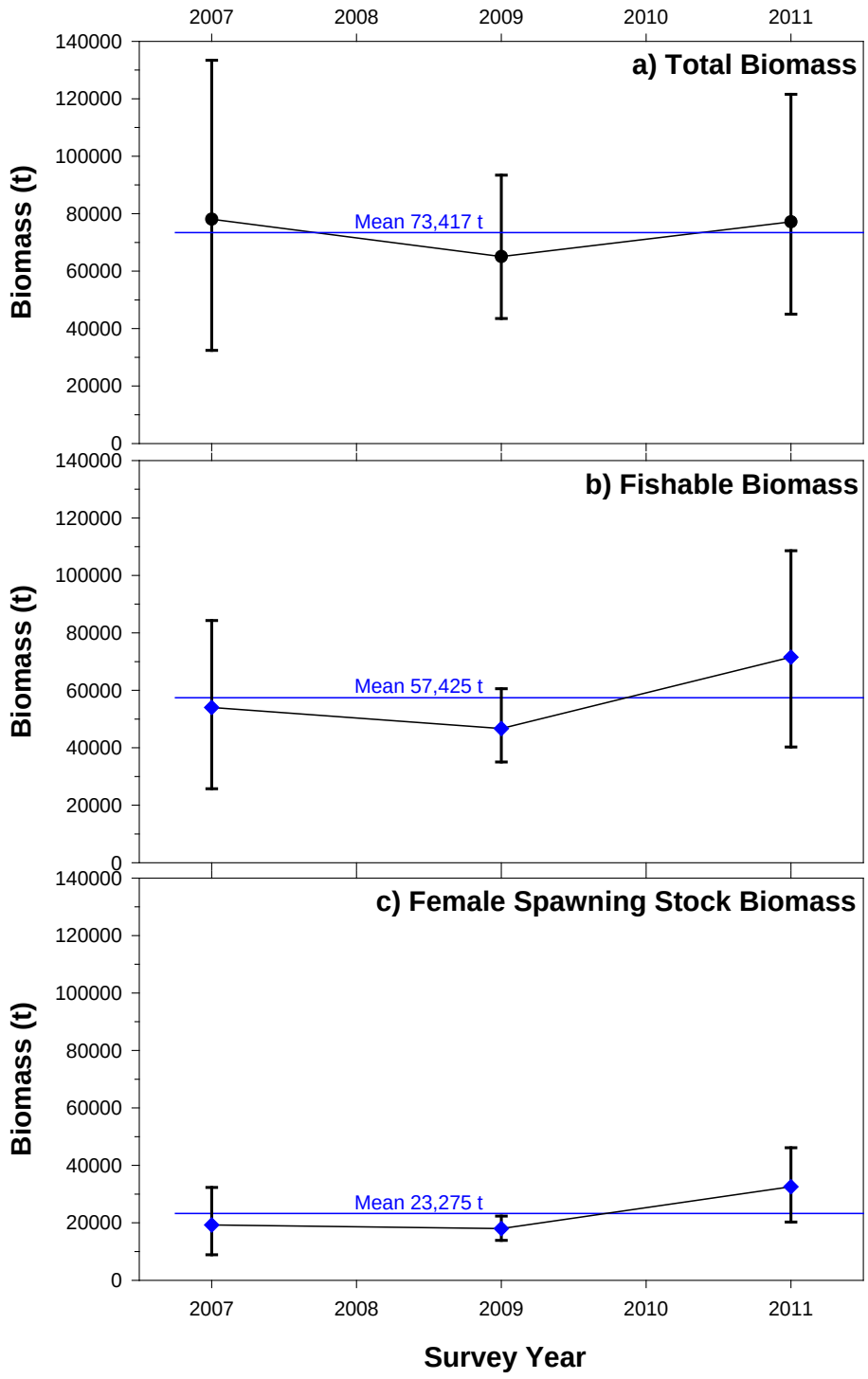

Figure 41. Total, fishable and female spawning stock biomass indices of Pandalus montagui in the Western Assessment Zone for the years 2007, 2009 and 2011. See Table 5 for associated data.

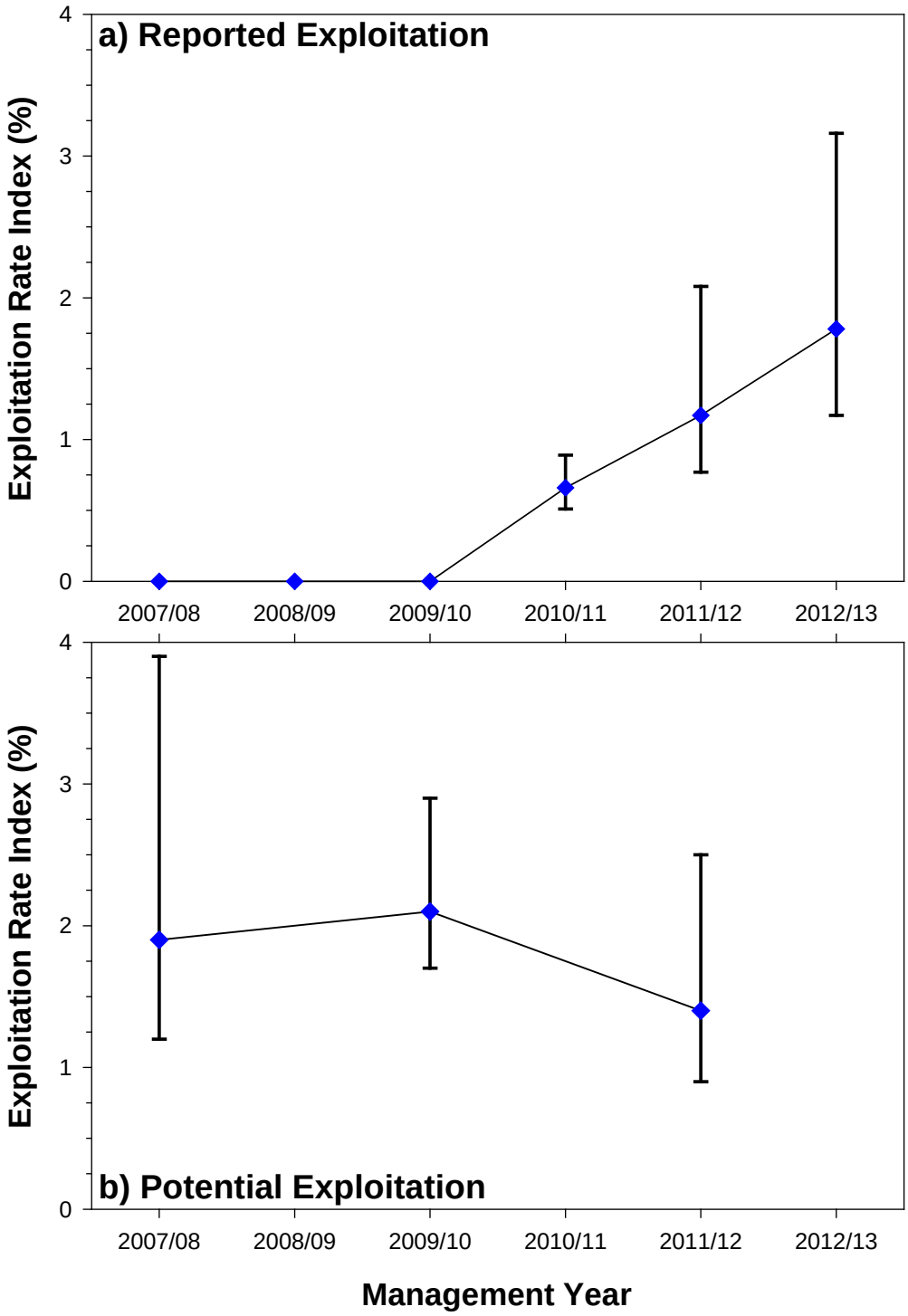

Figure 42. Western Assessment Zone Pandalus montagui exploitation rate indices for the a) reported rate, based on the catch taken and the b) potential rate if the entire TAC assigned to the Western Assessment Zone was taken.

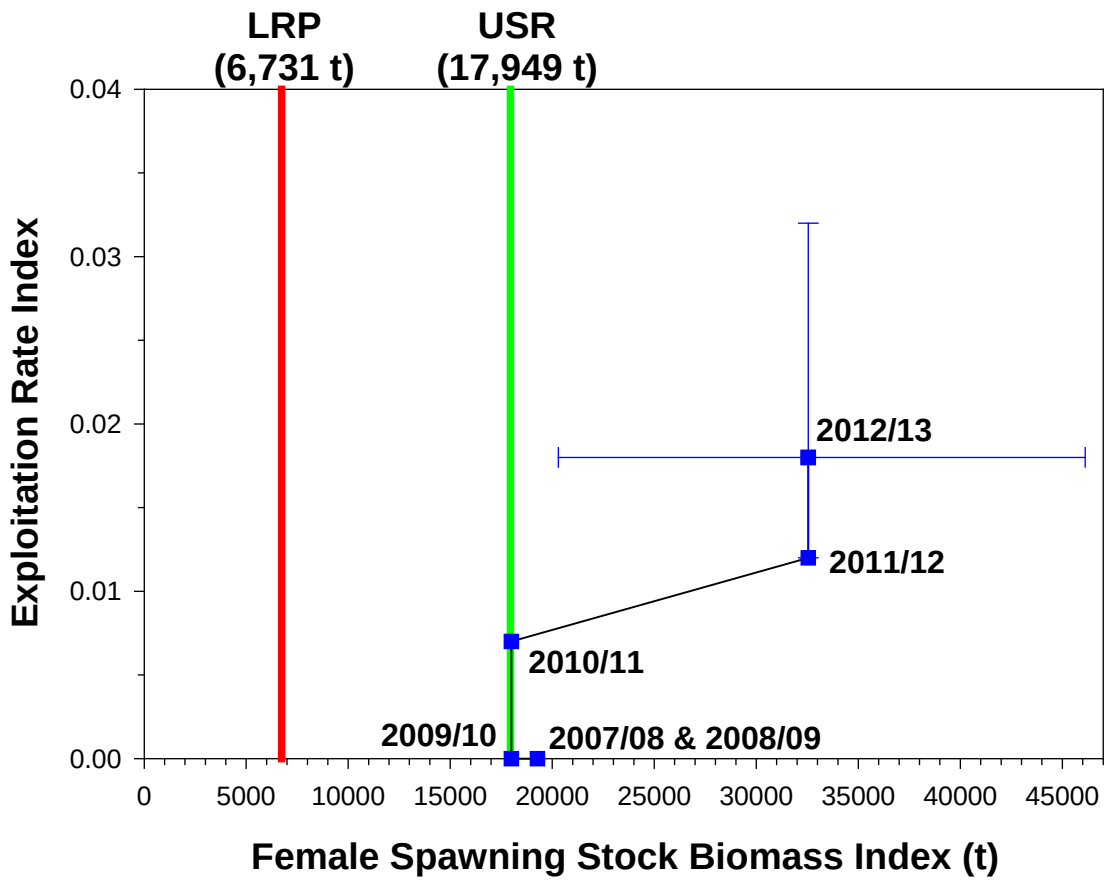

Figure 43. Western Assessment Zone trajectory of Pandalus montagui *female spawning stock and exploitation rate in reference to provisional limit reference points calculated using the proxy developed at two CSAS workshops in 2009. USR=Upper stock reference and LRP=limit reference point referring to 80% and 30% respectively of the geometric mean of the female spawning stock biomass indices from the 2007, 2009, and 2011 surveys. Since the area is surveyed biennially, exploitation rates from years without a survey were calculated assuming the population had not changed from the survey conducted the previous year.*

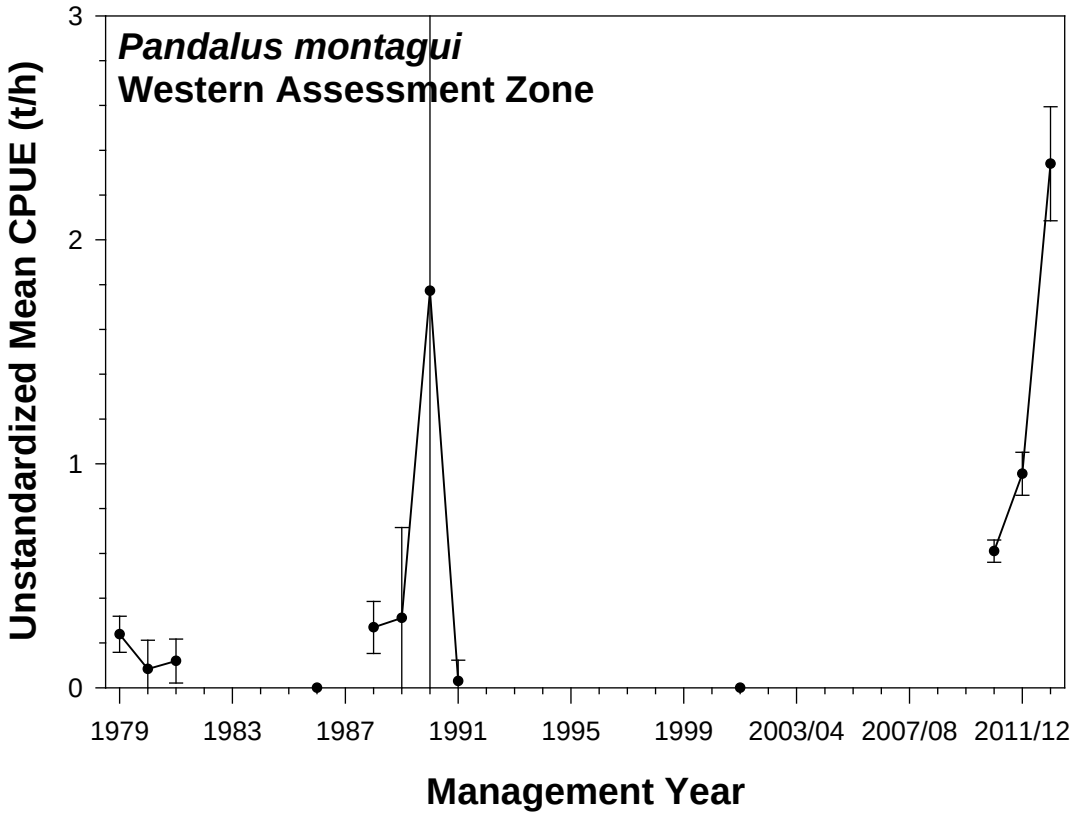

Figure 44. Unstandardized CPUE index for directed Pandalus montagui fishing in the Western Assessment Zone. Observer records for 2012/13 season may be incomplete.