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ASSESSMENT OF THE ARCTIC SURFCLAM (*MACTROMERIS POLYNYMA*) STOCK OF BANQUEREAU FOR 2016

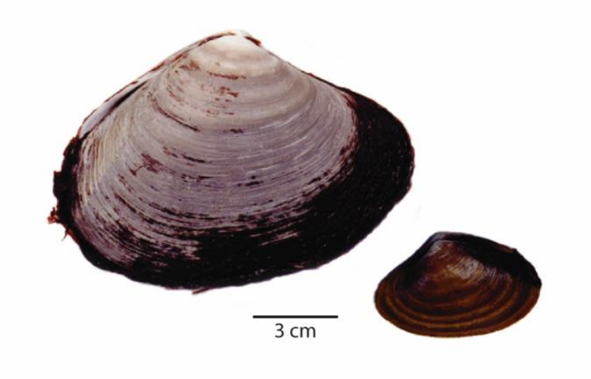

Photo Credit: Dale Roddick

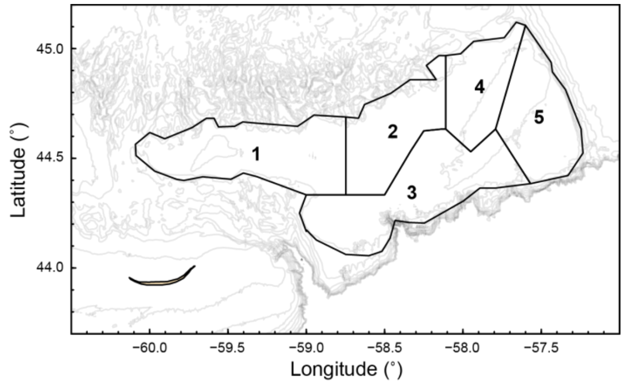

Figure 1. Map of Banquereau, Nova Scotia with spatial assessment areas (1-5).

Context:

*The hardshell clam fishery on Banquereau started with an exploratory fishery in 1986. The targeted species on this bank is Arctic Surfclam (*Mactromeris polynyma*). Fishing from large freezer processors is conducted using hydraulic dredges on sandy substrates located at 60-110 m depth.*

The management methods for the offshore clam fishery can be found in the Offshore Clams Integrated Fishery Management Plan, Maritimes and Newfoundland and Labrador regions (DFO 2014). The main management tools for the offshore clam fishery are limited entry licences, a Total Allowable Catch (TAC) divided into Enterprise Allocations (EAs), 100% industry-funded dockside monitoring, mandatory logbooks, and 100% Vessel Monitoring System (VMS) coverage.

There are currently three licences for four offshore clam vessels, with two vessels actively fishing on Banquereau, Nova Scotia, and one vessel fishing on Grand Bank, Newfoundland. Effort has switched back and forth between these areas over time, with effort concentrated on Banquereau during 2006-2015 and both banks fully harvested in 2016.

Indicator reports are produced annually as interim-year updates to determine whether there has been a change in stock status that may warrant a full stock re-assessment and revision of the science advice ahead of the assessment schedule or changes to management measures. The main indicators used in this assessment are derived from landing, logbook, and commercial catch sampling data.

A review of Arctic Surfclam science and a framework for the Banquereau stock of Arctic Surfclam took place in 2016 (DFO 2016). This assessment uses the methods from this recent framework to provide a summary of the current status of the Banquereau stock.

This Science Advisory Report is from the April 20-21, 2017, meeting on the Assessment of Arctic Surfclam. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule] as they become available.

SUMMARY

- The framework for Arctic Surfclam on Banquereau (DFO 2016) recommended the use of a surplus production model fit to a time series of Catch Per Unit Effort (CPUE) data from five spatial assessment areas where areal expansion of Surfclam density was limited to an estimation of suitable clam habitat.
- Vessel Monitoring System (VMS) location data was used to construct a proxy for suitable clam habitat by assuming that fishing effort is related to Surfclam density and has targeted all areas with commercial concentrations over the past 13 years. The resulting polygons of fished area showed a high degree of overlap with areas of high habitat suitability estimated from an independent analysis using predictors derived from multibeam sonar data.
- The distribution of Surfclam is a key factor to consider in the management of the resource. The previous bank-wide estimate of Surfclam biomass from the 2010 survey did not include uncertainties related to dredge efficiency, gear selectivity, or the patchy distribution and density of clams across the Bank.
- The production model permits the uncertainties in CPUE and the estimates of dredge efficiency to be quantified and propagated into the biomass estimates.
- The annual CPUE index has generally declined in most assessment areas since the 2010 assessment, with an increase in 2016.
- Exploitation rates have varied between 0 and 0.15 as the fishery shifted focus among areas. Spikes in exploitation are generally followed by reduced exploitation in subsequent years and do not typically occur in multiple areas in the same year.
- The Banquereau Arctic Surfclam stock is considered to be in the Healthy Zone, with the median modelled biomass estimates above all of the biomass reference levels (limit reference point, upper stock reference and CPUE of 70 g/m^2) for all of the assessment areas.
- Setting potential harvest levels based on the estimated biomass in the fished areas would increase the likelihood that the areas that have supported a commercial fishery since 1986 are not depleted. Setting potential harvest levels based on an estimated biomass for the full Bank could increase the likelihood that these historically fished areas might be depleted.
- The proposed fishing mortality level of 0.5 F_{MSY} would result in a Total Allowable Catch (TAC) of 20,943 t for Banquereau, which is comparable to the current TAC (24,000 t).

BACKGROUND

Species Biology

The Arctic Surfclam (*Mactromeris polynyma*) is a large, long lived species found mainly in coarse sand bottoms. It is a strong, active burrower, capable of burrowing several centimetres below the sediment surface (typically to the depth of the siphon). A distinguishing feature is that most specimens have a purple colour in the foot and mantle that turns red upon cooking, similar to lobster and shrimp.

In the western Atlantic, Arctic Surfclam are distributed from the Strait of Belle Isle to Rhode Island. In the Pacific, they are found from the Juan de Fuca Strait to Point Barrow, Alaska, and also from Sakhalin Island, Russia. All Atlantic populations are from the sub tidal down to 110 m, but in Alaska there are intertidal populations as well.

Slow growing and long lived, significant numbers of Surfclams appear to reach 40 years of age. On Banquereau, the oldest animal aged so far was 92 years old, and the largest observed was 159 mm in shell length. The age and size at 50% maturity was determined to be 8.3 years and 45.2 mm in shell length. Based on life-history and selectivity parameter (15.3 years) estimates, the age of maximum biomass per recruit occurs near the age of 50% selectivity of the commercial gear; therefore, growth overfishing is unlikely to occur. The age at 50% maturity is also below the age of 50% selectivity, and suggests that an average Surfclam on Banquereau could have the opportunity to spawn over a period of 7 years before being recruited to the fishery. These spawning opportunities should help ensure that recruitment overfishing does not occur, although there have been no studies of the relative fecundity of young versus older Surfclams.

Fishery

Following a 3 month test fishery in 1986, an offshore Clam Enterprise Allocation Program was developed for Arctic Surfclams on Banquereau. The initial Total Allowable Catch (TAC) of 30,000 t was reduced to 24,000 t in 2000 following the 1996-97 Banquereau survey. Expansion of the fishery to Grand Bank (3LNO) happened in 1989, after exploratory fishing in 1987 and 1988, with a “precautionary” TAC of 20,000 t. The TAC was based on an economic break-even analysis, as there was little information on the available biomass in the area. With no biological advice on biomass and the TAC never being reached, the TAC for Grand Bank continued at the same level until after the 2010 Grand Bank assessment, when the TAC was adjusted to 14,756 t in 2011. Three vessels have been active for most of the fishery. The offshore fishery is pursued by large freezer processors that fish on Banquereau, Nova Scotia, and Grand Bank, Newfoundland. Effort has switched between these areas over time, with effort concentrated on Banquereau (Figure 1) during 2006-2015 and full quotas caught for both banks in 2016 (Figure 2).

The majority of the fishing effort (95%) on Banquereau has focused on an area of approximately 20% across the Bank, while the catches on Grand Bank have concentrated on a small portion of the Bank to date.

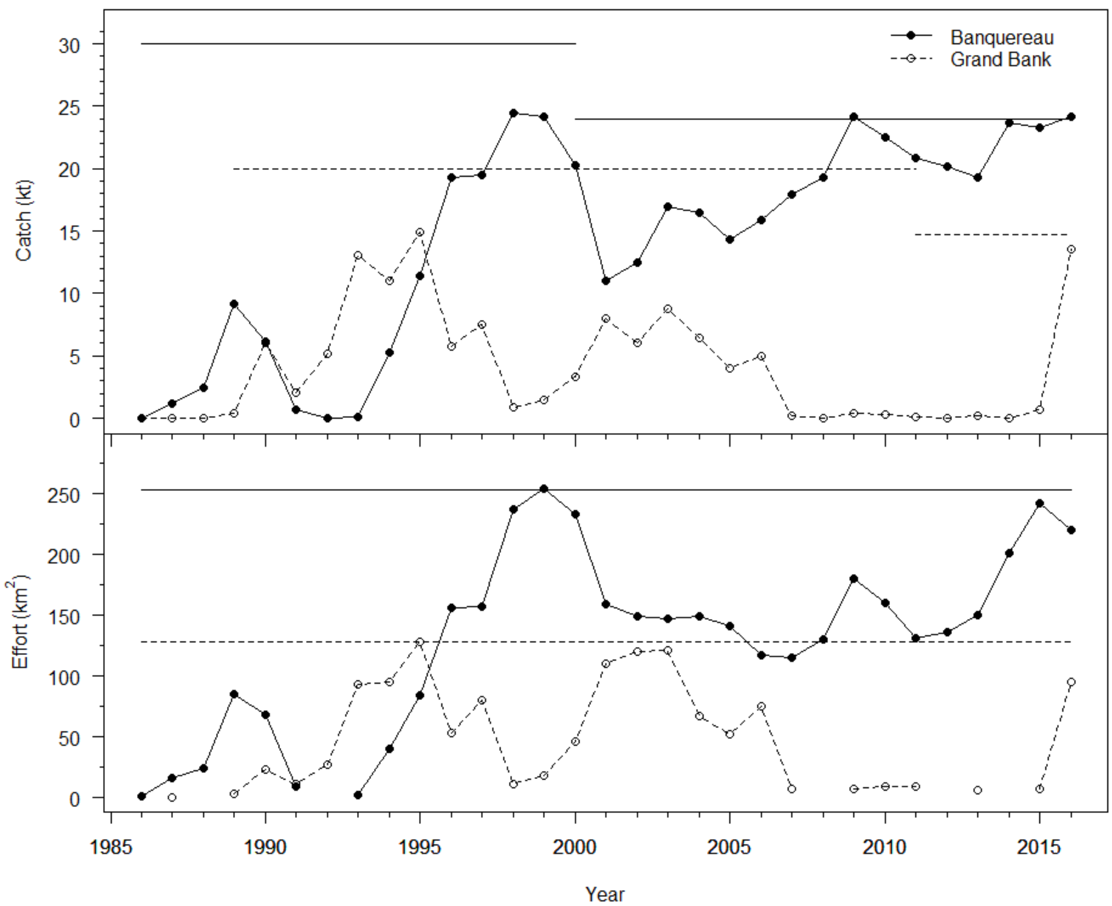

Figure 2. Annual catch (top panel) and effort (bottom panel) for the Arctic Surfclam fishery on Banquereau and Grand Bank from logbook data. Horizontal lines represent TAC levels for catch and trigger levels for effort for Banquereau (solid lines) and Grand Bank (dashed lines). Discard data are not included.

Survey

Four surveys of Banquereau have been conducted since the start of the fishery: 1980–1982 (Chaisson and Rowell 1985, Rowell and Chaisson 1983), 1996–1997 (Roddick and Smith 1999), 2004 (Roddick et al. 2007), and 2010 (Roddick et al. 2012). Results from an assessment of the 1996–1997 survey of Banquereau (DFO 1999) led to a reduction of the TAC for Banquereau from 30,000 t to 24,000 t in 2000. Two surveys of Grand Bank have been conducted since the start of the fishery: 1995–1997 and 2006–2009 (Roddick et al. 2011). An assessment of these surveys lead to a reduction of the TAC for Grand Bank from 20,000 t to 14,756 t in 2011.

The bank-wide distribution of Arctic Surfclams was estimated from the 2010 survey using inverse distance weighting interpolation (Figure 3). The total biomass estimate from the 2010 survey is provided in the 2010 Assessment Report (DFO 2012) and was calculated by multiplying the average density across survey tows, corrected for selectivity and dredge efficiency (113.8 t/km^2), by the total area of the Bank (10,110 km^2) which results in a bank- wide biomass estimate of 1,150,585 t (DFO 2012; Roddick et al. 2012). The estimate did not include uncertainties related to dredge efficiency, gear selectivity, or the patchy distribution and density of clams across the Bank.

Some of the distribution patterns resulting from the survey data are consistent with the fishery information; however, given the highly patchy nature of the resource, the density of sampling in the survey is insufficient to adequately describe the distribution of clams across the Bank.

The consensus statements from the 2016 framework indicated that the decline in catch rates since 2011 supported the need for an updated assessment approach. The spatial production model presented at the meeting was considered suitable to assess stock status because it incorporated a reasonable proxy for habitat suitability, accounted for variable trends in Catch Per Unit Effort (CPUE) at smaller spatial scales and addressed the variability in the available data. Similar approaches have also been used in other sessile bivalve fisheries where fishing effort is concentrated in the most productive areas (Smith et al. 2012).

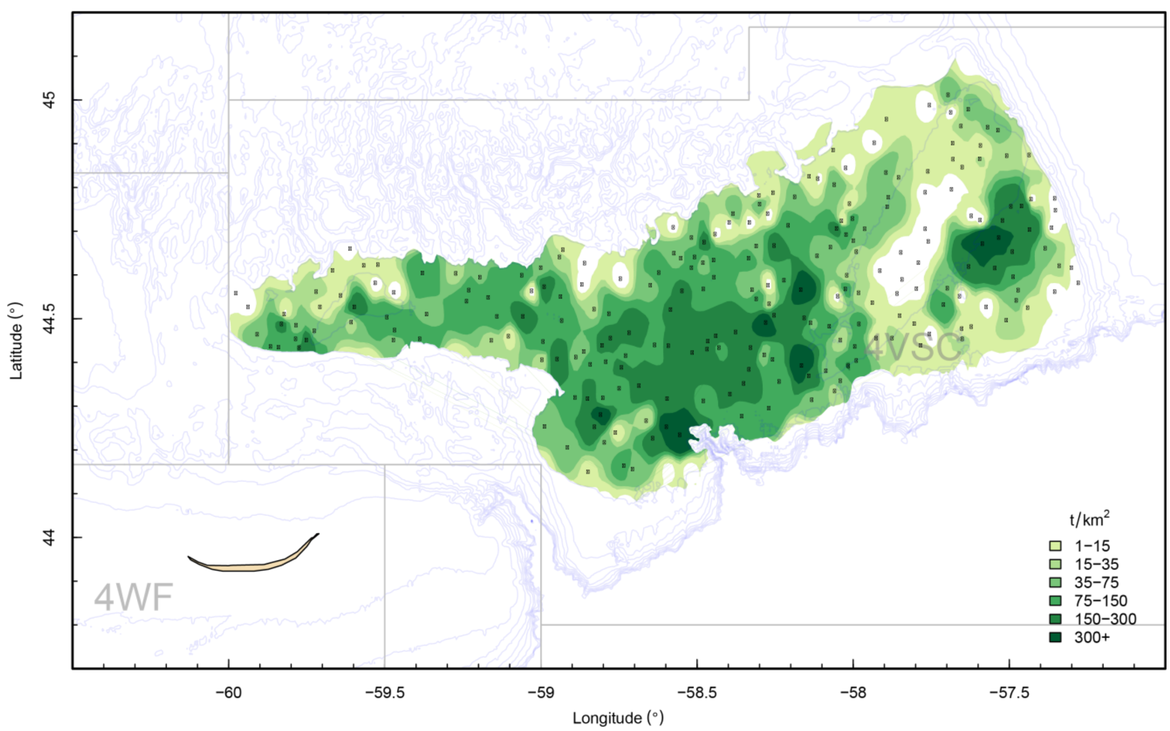

Figure 3. Contour plot of the estimated biomass density of Arctic Surfclam (tonnes/km^2) from the 2010 Banquereau offshore survey (DFO 2012?).

ASSESSMENT

Stock Trends and Current Status

The framework for Arctic Surfclam on Banquereau (DFO 2016) recommended the use of a surplus production model fit to a time series of CPUE data from five spatial assessment areas where areal expansion of Surfclam density (g/m^2) was limited to an estimation of suitable clam habitat. Five proposed spatial assessment areas were proposed and accepted at the 2016 framework to facilitate the modelling of the biomass of Arctic Surfclam on Banquereau (Figure 1; Hubley and Heaslip, in prep).

The annual CPUE index (Figure 4) has generally declined in most assessment areas since the 2010 assessment, with an increase in 2016. Improvements in fishing efficiency (e.g., changes in gear and habitat mapping technology utilized by industry) have been noted by the license holder. In order to compare current estimates with those of the last stock assessment, biomass was estimated from the CPUE densities by expanding to the total fished area without an adjustment for catchability (q = 1). In 2010, with the same conservative assumption that q = 1, the estimated fishable biomass for all areas was 211,136 t from the 2010 survey data and was 218,262 t from the 2010 CPUE data. Although the estimates for fishable biomass were similar between the 2010 survey and CPUE data over the entire area, there was a greater amount of variability between these 2 data sources when the biomass was partitioned among the 5 individual assessment areas (Hubley and Heaslip, in prep.), which may reflect that the survey did not adequately account for uncertainty and variable density of clam beds. As an additional comparison, the biomass from the CPUE density expanded to the total fished area without a correction for catchability would be 179,633 t for 2016.

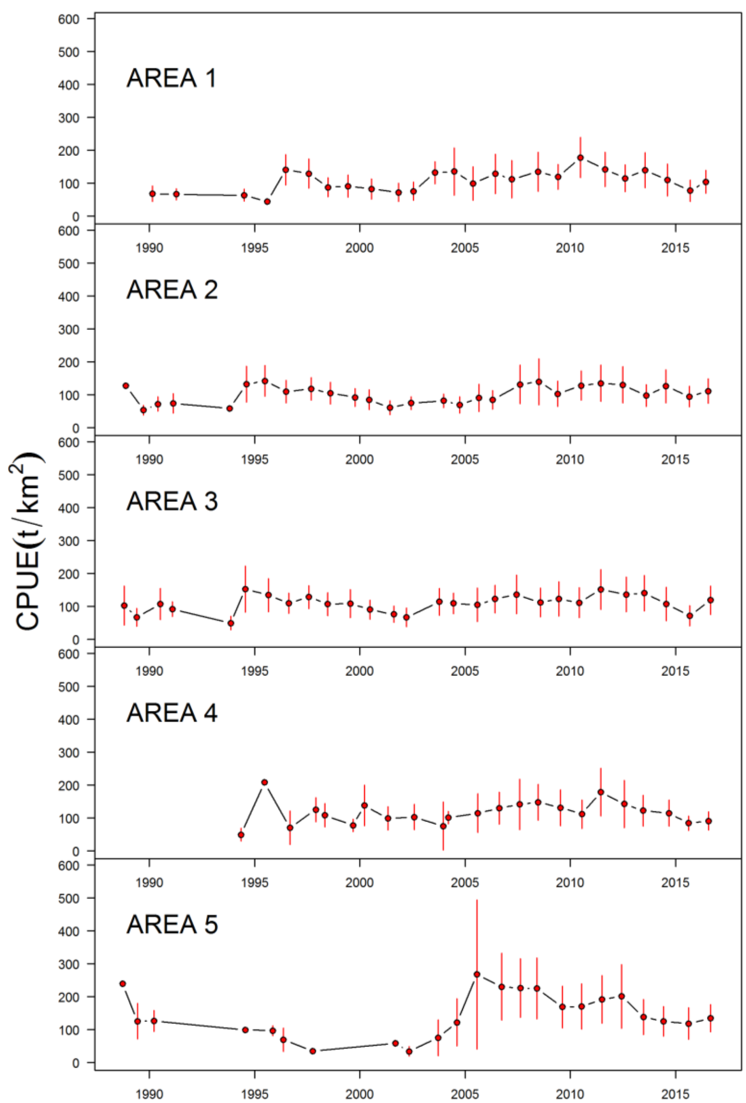

Figure 4. Catch per unit effort (CPUE) by spatial assessment area showing the annual mean values (red points) ±1 standard error (red lines) for 1988–2016.

Habitat Suitability

The distribution of Surfclam is a key factor to consider in the management of the resource. The patchiness of the distribution complicates the provision of harvest advice based on a presumed bank-wide biomass instead of areas that are harvested (Hoenig 2015[1]). Ideally, ground-truthed fine scale habitat information could be used to predict Surfclam habitat using relevant covariates that are related to Surfclam abundance and distribution. Currently, these types of data and associated predictive models are unavailable. In lieu of this information, high resolution Vessel Monitoring System (VMS) location data with an hourly transmission frequency was used to construct a proxy for suitable clam habitat by assuming that fishing effort is related to Surfclam density and has targeted all areas with commercial concentrations over the past 13 years (i.e., since VMS was implemented in 2004). This approach cannot be reliably applied to Grand Bank given the low level of accumulated fishing effort since 2004 (Figure 2) and the low coverage of this effort over this larger bank.

On Banquereau, the density of VMS locations was estimated from 2004-2016 using a kernel density method with a standard deviation (bandwidth) of 0.2 (Figure 5). The Vessel Monitoring System density is expressed as the number of transmissions per km^2, with a resolution of 100 m^2, so the number of transmissions per km^2 was estimated for every 100 m^2. A density level of 30 transmissions per km^2 (≥30 hours of fishing effort per 1 km x 1 km cell over the 13 year period) was chosen to define the fished areas. These fished areas were used as a proxy for clam habitat that can support a fishery. The estimated area of viable clam habitat is sensitive to this density threshold, and an analysis comparing high resolution habitat suitability models should be used to refine or corroborate this threshold (Hubley and Heaslip, in prep.).

An independent analysis of habitat suitability using predictors derived from multibeam sonar data, has been conducted for key areas of Banquereau by Dr. Craig Brown (NSERC Industrial Research Chair in Ocean Mapping at the Nova Scotia Community College) under a collaborative research project with industry. Dr. Brown presented this work at the assessment meeting. Further analyses are required to explore the relationship between habitat suitability and VMS density or clam density, and to integrate habitat suitability models into the clam assessment methodology.

[1] Hoenig, J.M. 2015. Review of the Scientific Basis for Managing Stocks of Arctic Surfclam on Banquereau and Grand Bank: Data, Analysis, and Overall Inference. (unpublished manuscript)

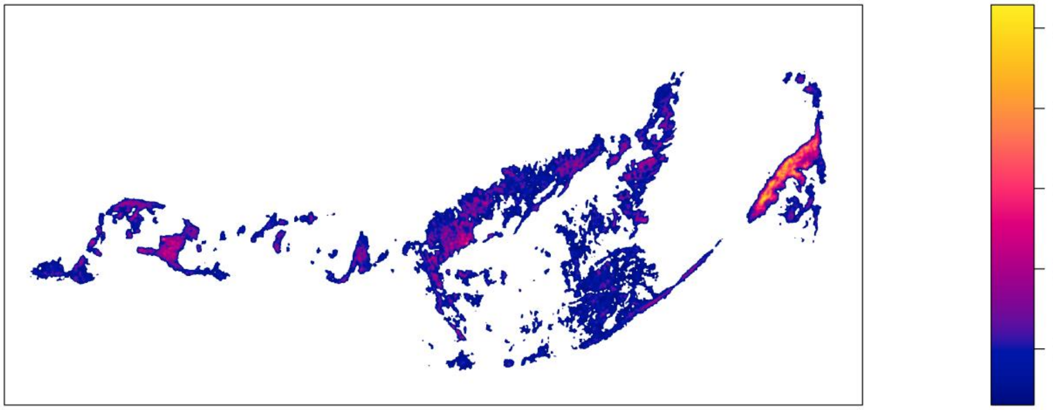

Figure 5. Vessel Monitoring System (VMS) density estimated from a kernel smoothed intensity function with a standard deviation of 0.2 on a 100 m^2 resolution. The scale bar shows VMS intensity expressed as the number of transmissions (pings) per km^2 for 2004–2016. The colored region shows the area where VMS intensity is greater than 30 pings/km^2.

Spatial Production Model

Fished Areas

For assessment purposes, the stock definition has been restricted to the area directly under exploitation instead of a definition of the bank based solely on areas with <100 m depth. Along with the delineation of the five areas, this restricted stock definition allowed for the effect of the fishery to be modelled using the CPUE data, which are the only new data available since the last assessment. The Spatial Production Model (SPM) is a surplus production model fit simultaneously to each assessment area with some parameters shared across areas implemented in a Bayesian state space framework. Carrying capacity (*K*) was assumed to be related to the habitat area within each area and productivity (*r*) was estimated for each area but constrained by a hierarchical structure where the overall mean and standard deviation is estimated for all areas. Catchability was informed by the dredge efficiency estimates from the last assessment. The estimates of *r* varied only slightly between areas. The median estimate of dredge efficiency (0.39) was lower than the maximum likelihood estimate of the of the survey dredge efficiency experiment (0.45, 95% Confidence Interval (CI) 0.21–0.86) presented for the last assessment (Roddick et al. 2012).

In general, biomass increased in the early 2000s across all areas, but has declined since 2010 (Figures 6, 7, and Table 1). Exploitation rates have varied between 0 and 0.15 as the fishery shifted focus among areas. Spikes in exploitation are generally followed by reduced exploitation in subsequent years and do not typically occur in multiple areas in the same year (Figure 8).

Table 1. Biomass estimates (tonnes) from the spatial production model.

Year	Area 1	Area 2	Area 3	Area 4	Area 5	Total
2010	123,966	164,725	147,533	72,839	94,772	603,835
2011	116,653	164,424	162,810	83,547	95,132	622,566
2012	105,688	160,248	160,312	76,792	93,167	596,207
2013	105,230	145,994	154,263	67,725	80,173	553,385
2014	91,811	152,498	134,693	60,144	72,519	511,665

Year	Area 1	Area 2	Area 3	Area 4	Area 5	Total
2015	78,023	137,511	117,572	54,002	70,552	457,660
2016	84,091	139,978	132,869	54,377	64,632	475,947

Areas Outside the Fishery Footprint (Fished Areas)

A proposal was made to subtract the 2016 biomass estimated from the SPM for the fished area from the total biomass estimate from the 2010 assessment (which was derived from the 2010 survey). There was considerable concern with this approach, for numerous reasons, including: the high and unquantified uncertainty of the estimate from the 2010 survey; the fact that biomass estimates from the survey are 7 years old and biomass has likely changed, which CPUE indicates has occurred in the fished areas; the 2010 survey biomass estimate averaged clam density across the whole bank and thus did not address the patchy distribution of suitable clam habitat (high and low densities); and finally, estimates from the survey and SPM were based on different methodologies and assumptions. For example, with regard to the uncertainty of the 2010 estimate, if only uncertainty related to the dredge efficiency was considered (0.45, 95% CI 0.21–0.86), the 2010 biomass estimate would range in fact from 602,050 t to 2,465,539 t. If a precautionary approach was employed, assuming dredge efficiency (q) = 1, the biomass estimate from the 2010 survey would be 517,763 t, which is less than the SPM estimate for 2010 (Table 1) where q was estimated as 0.39. The survey biomass estimate is the result of an extrapolation from just 7 t of clams captured during the survey from 239 survey tows. In comparison, the SPM biomass estimates are derived from the time series (average of 14,676 hours of fishing per year) and take into account the effect of the annual landings on CPUE of each area and directly incorporate the variability in CPUE and estimates of dredge efficiency.

In order to properly address the question of fishable biomass in areas that have not been previously exploited, the quality of clam habitat needs to be examined for the entire Bank. This may be accomplished with a post-stratification based on ground-truthed habitat suitability, or preferably, by using a continuous index of habitat suitability as a weighting factor for abundance. The 2004 and 2010 survey data could be useful in determining the suitable habitat in unfished areas. These alternative methods should be evaluated (e.g., quantify the uncertainty of biomass estimates outside the fished areas, simulation test and field validate.

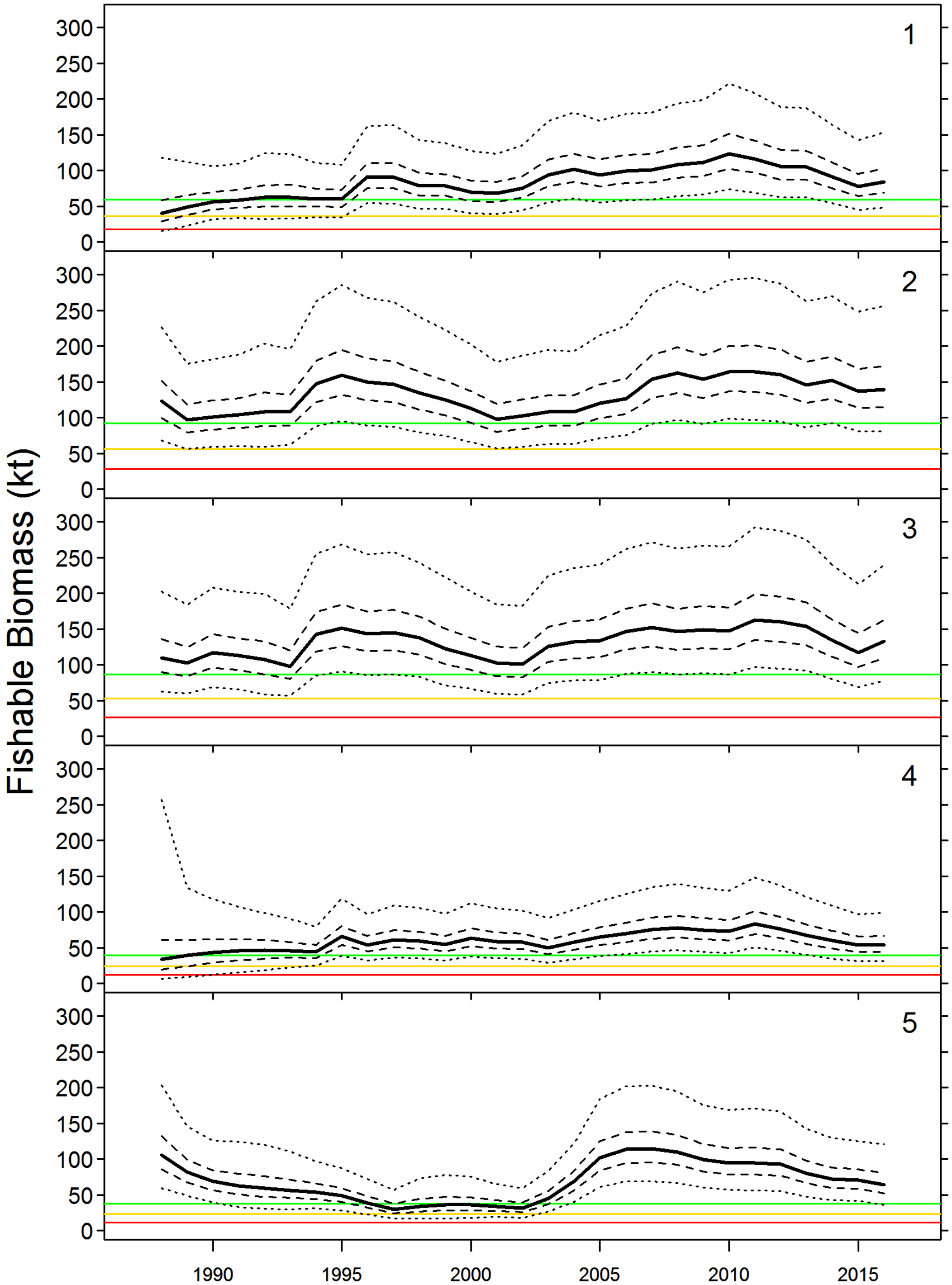

Figure 6. Estimates of biomass (fishable biomass in kilotonnes) from 1988–2016 from the spatial production model by assessment area. Lines denote the median (solid), 50% credible interval (dashed), and 95% credible interval (dotted). The colored lines represent the LRP (red), USR (yellow) and CPUE (green) reference points.

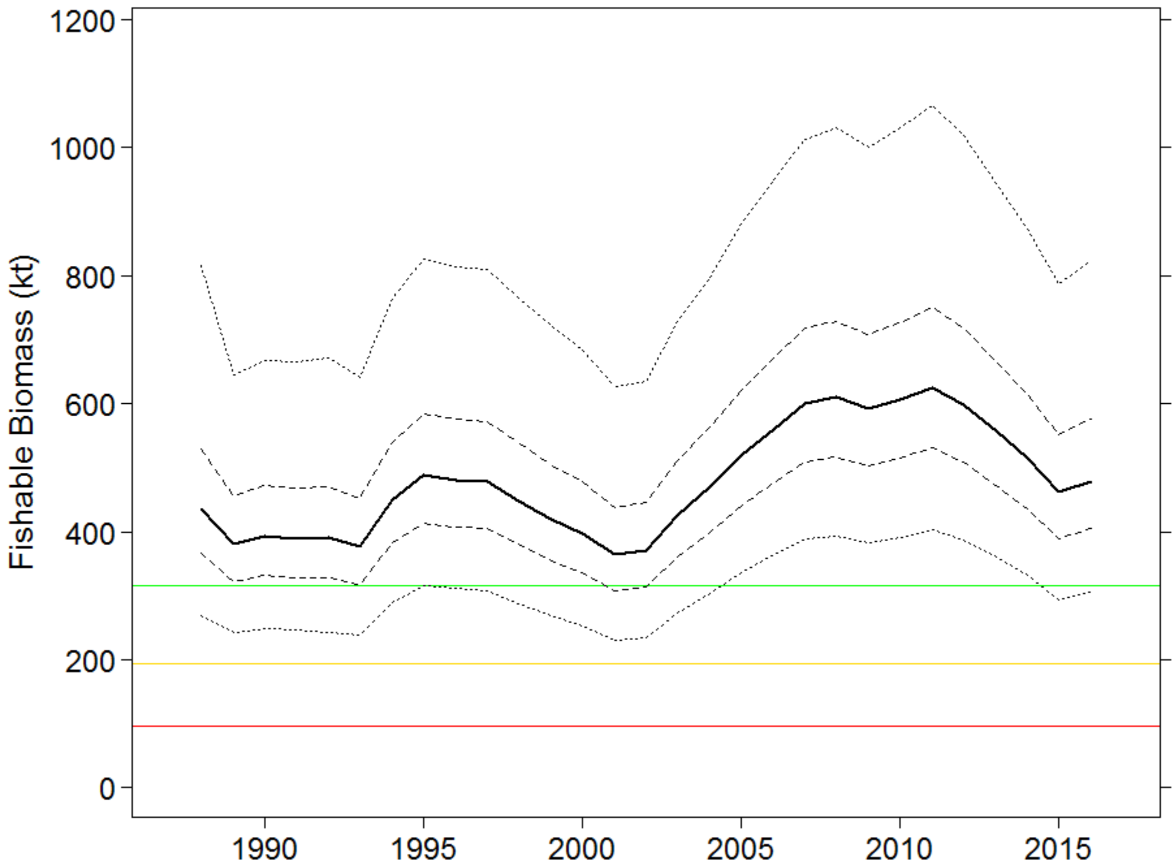

Figure 7. Estimates of biomass (fishable biomass in kilotonnes) from 1988–2016 from the spatial production model for the total fished area. Lines denote the median (solid), 50% credible interval (dashed), and 95% credible interval (dotted). The colored lines represent the LRP (red), USR (yellow) and CPUE (green) reference points.

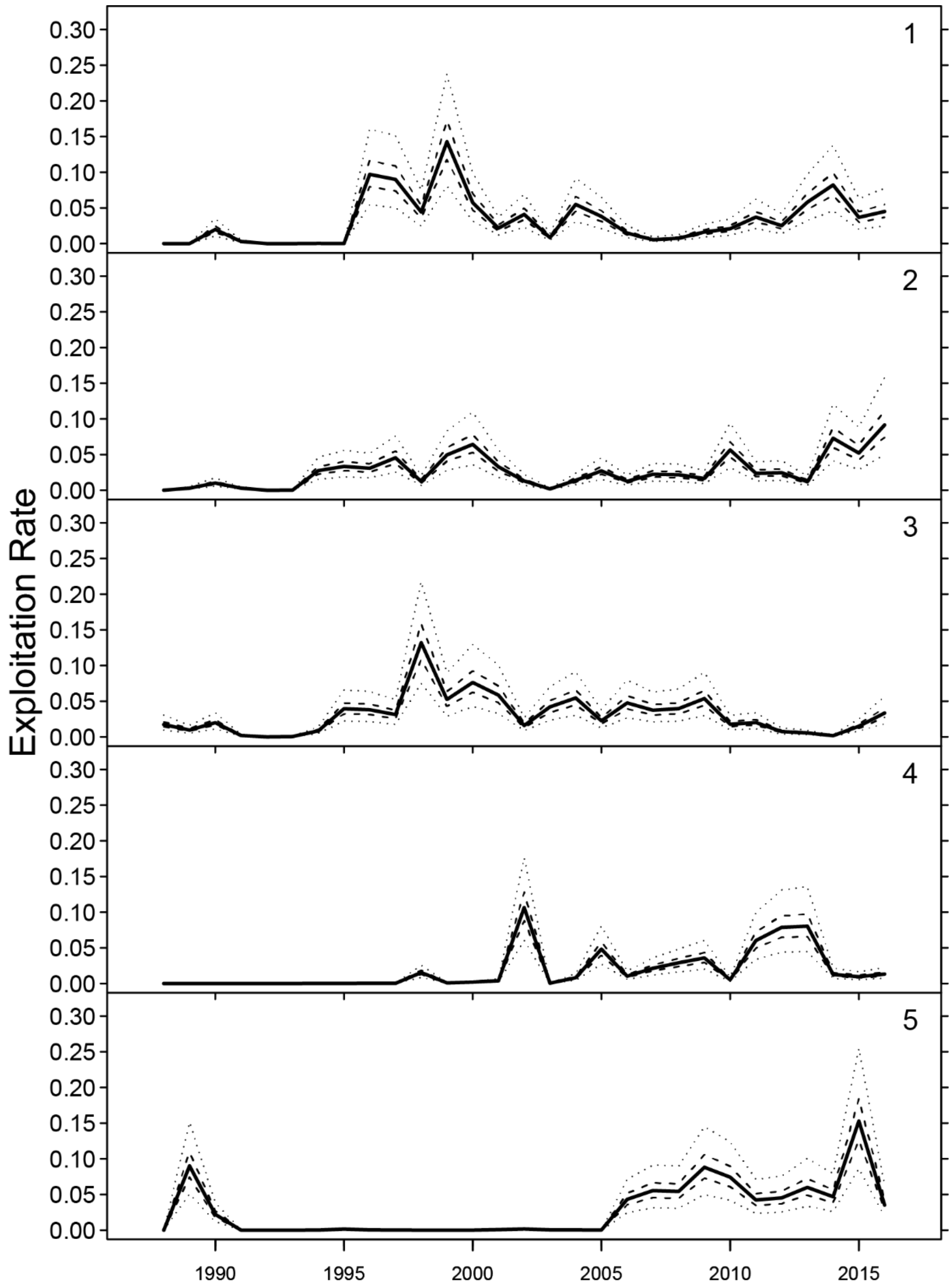

Figure 8. Estimates of exploitation rate for 1988–2016 from the spatial production model by assessment area. Lines denote the median (solid), 50% credible interval (dashed), and 95% credible interval (dotted).

Reference Points

The surplus production model was used to calculate the default 0.4 and 0.8 B_{MSY} (Biomass at Maximum Sustainable Yield) normally used to define the limit reference point (LRP) and upper stock reference (USR). These reference points were compared to the CPUE trigger level of 70 g/m^2 ($CPUE_{70}$) used in annual indicator reports (Roddick et al. 2012) by adjusting how 70 g/m^2 would translate into modeled biomass estimates for each area (Table 2). It is useful to include this value as it corresponds with the lowest observed value in the time series, which is often used as a potential default for the LRP. In this case the $CPUE_{70}$ values were higher than the estimates of B_{MSY}, suggesting that B_{MSY} is underestimated. These biomass reference levels along with removal reference levels of 0.5 F_{MSY} (Fishing Mortality at MSY) and 0.33M (0.0264) (where M is natural mortality) are shown on the phase plots (Figure 9). The removal reference level of 0.5 F_{MSY} was proposed as an intermediate value between 0.33M, which was developed for a larger less productive stock area, and F_{MSY} which appears to be overestimated (see Sources of Uncertainty) it is greater than any observed F levels. Due to the uncertainties in estimating B_{MSY} reference points, it is recommended that the current trigger level reference point of $CPUE_{70}$ is maintained as an interim approach, to be re-evaluated at the next assessment.

Table 2. Biomass reference point $CPUE_{70}$ compared with the limit reference point *(LRP) and upper stock reference (USR) based on B_{MSY} for each proposed assessment area (1-5) and for total area.*

Area	$CPUE_{70}$	LRP	USR	B_{MSY}
1	59,339	18,195	36,389	45,487
2	92,619	28,377	56,753	70,942
3	86,514	26,513	53,026	66,283
4	39,479	12,101	24,202	30,252
5	38,226	11,720	23,441	29,301
Total	316,178	96,906	193,812	242,265

Status Relative to Reference Points

The Banquereau Arctic Surfclam stock is considered to be in the Healthy Zone, with the median modelled biomass estimates above all of the biomass reference levels (LRP, USR, $CPUE_{70}$) for all of the assessment areas (Figure 6). However, the CPUE index indicates biomass has decreased since the last assessment in 2010, particularly in area 5 and overall (Figures 6 and 7). It is recommended that potential harvest levels be applied to only the identified fished areas, because these are the only areas where we have recent information to support advice. Of the 3 potential F removal references, F_{MSY} is considered to be too high as declines in CPUE have been observed at significantly lower F levels. The proposed 0.5 F_{MSY} level would result in a TAC that is comparable to the current TAC for Banquereau (24,000 t), while the lower F level equivalent to 0.33M (0.0264) would result in a much lower TAC when applied to the fished area biomass (Table 4).

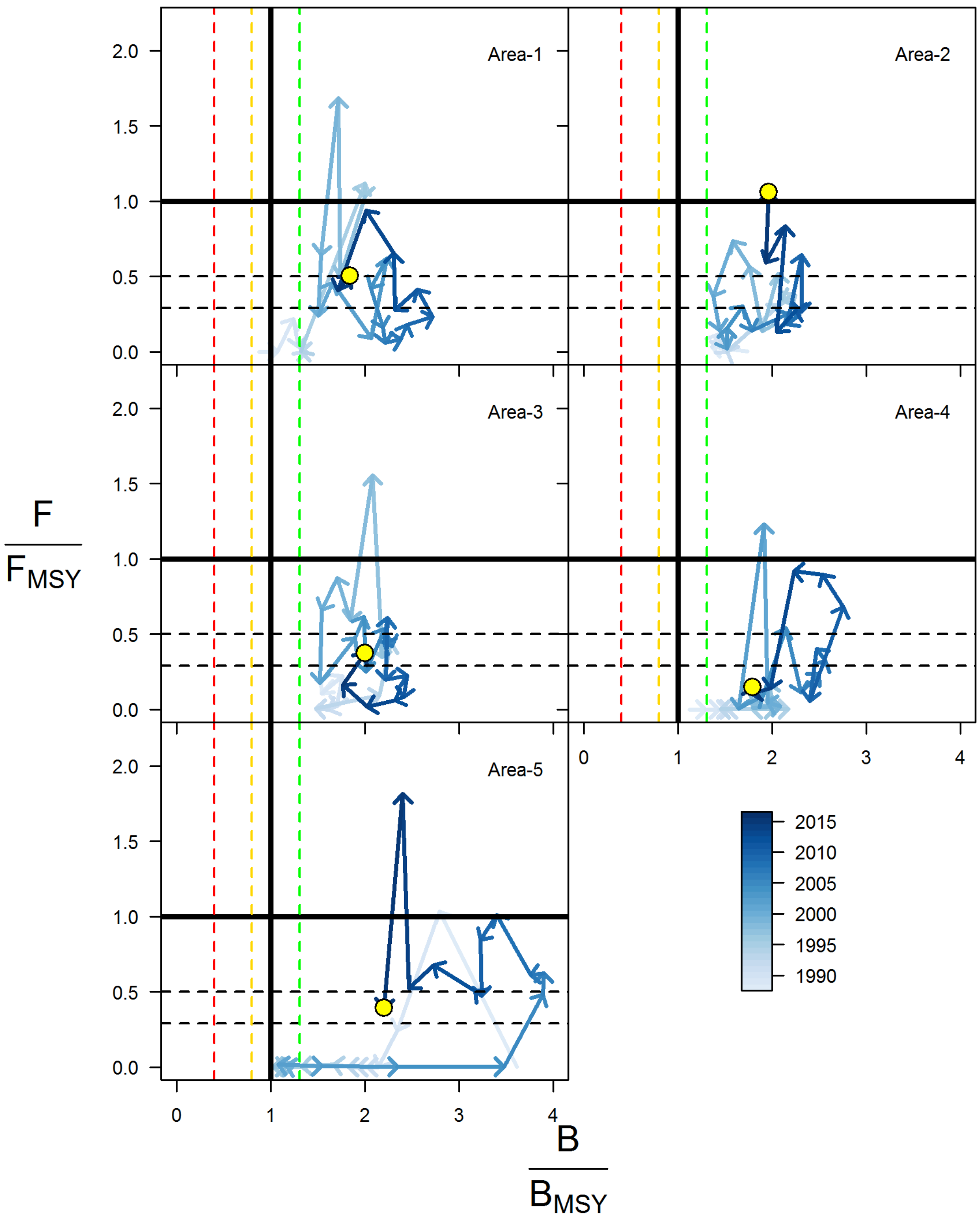

Figure 9. Phase plots showing spawning biomass relative to B_{MSY} (B/B_{MSY}) along the x-axis and fishing mortality relative to F_{MSY} (F/F_{MSY}) along the y-axis for each assessment area. The biomass reference levels are shown by the thick vertical line ($B/B_{MSY} = 1$), and colored dashed lines for the LRP (red), USR (yellow) and CPUE (green). The fishery mortality reference levels are shown by the thick horizontal line ($F/F_{MSY} = 1$) and dashed lines for $0.5F_{MSY}$ and 0.33M (0.0264). The colored arrows denote data for each year (1988–2016). The yellow circle denotes the 2016 estimates of relative biomass and fishing mortality.

Ecosystem Considerations

Habitat

The clam dredges used in the offshore clam fishery have an immediate impact on the substrate and benthic organisms because they liquefy the sediment down to at least 20 cm (8 inches), remove many large macro-infaunal organisms and cause sedimentation, and displace organisms adjacent to the track. On Banquereau, the long term impacts of a hydraulic clam dredge on the habitat and benthic community has been studied at a deep site of 65–70 m depth and followed over a 10 year period (Gilkinson et al. 2015, Gilkinson et al. 2003, Gilkinson et al. 2005). This study is considered one of the most rigorous fishing gear impact studies done to date.The largest quantified species impact is the removal of clams and other non-target bivalves from the area, both from harvesting and from incidental mortality. Given the sedentary nature of clams and their slow growth rate, this is a long term impact. The experiment demonstrated immediate impacts on both habitat and non-target organisms. Within the first two years following dredging, there was considerable recovery of the composition of non-target benthic species, such as echinoderms, with a shift in relative abundance of the species present. In addition, there were few juvenile clams in the experimental grab samples (pers. comm. Kent Gilkinson, DFO Newfoundland). Visual evidence of dredge tracks disappeared after one year; however, tracks were visible from sidescan sonar imagery (Gilkinson et al. 2005). In comparison, 6 of 12 tracks at less than 40 m depth on Sable Bank were not detected one year later (pers. comm., Ned King, Atlantic Geoscience Centre). Species composition in the dredged sites seemed to be dominated by colonizing species three years after dredging. Definite conclusions were complicated by similar changes in the reference sites, indicating an effect that extends beyond the disturbed area, variation unrelated to the dredging, or a combination of both (Gilkinson et al. 2005).

There was low recruitment of large bivalve species to the experimental study site over ten years post-dredging, and sidescan sonar was still able to detect some of the track locations ten years after dredging. Four commercial bivalve species (Arctic Surfclam; Northern Propellerclam, *Cyrtodaria silique*; Ocean Quahog, *Arctica islandica*; and Greenland Smoothcockle, *Serripes groenlandicus*) showed low recruitment at the experimental site over the 10-year post-dredging period, but a similar recruitment pattern was also observed in non-dredged areas suggesting that low recruitment is unlikely a result of dredging. The persistence of dredge tracks at deep sites suggests that water depth likely influences track persistence, with shallower areas having sediments that are more actively worked by waves and currents. Hydraulic clam dredge fisheries occur on fairly mobile, well-sorted sand, which may help mitigate the overall impact on some elements of the benthic community (NREFHSC 2002). There continues to be uncertainty about the long term impacts of dredges on overall benthic productivity.

With three vessels currently active in the offshore clam fishery, the swept area estimated in km^2 (footprint) is relatively small compared to the spatial extent of the target species and other mobile gear fisheries. Since 1986, approximately 3,898 km^2 have been swept on Banquereau; and since the Grand Bank Arctic Surfclam fishery began in 1989, approximately 1,279 km^2 have been swept, with most of this activity in 1990–2003 and 2016. These estimates of area swept are not corrected for overlapping of tows.

There is considerable spatial and temporal variation of area swept over the timeframe of the fishery with areas of high clam biomass fished more frequently and intensely than other sections and periods when the fishery has concentrated on Banquereau rather than Grand Bank. The average annual area swept during the last 10 years of the fishery (2007–2016) on Banquereau is approximately 167 km^2 and for Grand Bank is approximately 20 km^2 (Figure 2). Since the target species is one of the longer lived species in the benthos, it will be one of the last species to recover from fishing. If a vessel does not return to an area fished prior to the recovery time of the Arctic Surfclam, this should allow the shorter lived, faster growing species time to recover before the area is fished again.

The total area swept during the last two years of the fishery on Banquereau (2015–2016) is approximately 462 km^2 or approximately 5% of the Bank. Though the fishery footprint provides a spatial index relative to the size of the Bank (approximately 10,100 km^2), it does not consider that the impacts of fishing activity are likely cumulative since Surfclam are sessile and recruitment probably occurs at a decadal time scale (Gilkinson et al. 2015). Cumulative fisheries footprints have plateaued near estimated available fished area for Banquereau (approximately 1600 km^2), suggesting that estimates of fishable area and a 10 year recovery period are likely appropriate for this stock.

Hydraulic clam dredge fisheries occur on fairly mobile, well-sorted sand, which helps mitigate the overall impact on some elements of the benthic community (NREFHSC 2002); however, there continue to be uncertainties about the long term impacts of dredges on overall benthic productivity.

Assessment Frequency and Interim Updates

It was proposed and agreed upon that that Banquereau stock of Arctic Surfclam would be assessed every five years, with interim Science Response reports conducted annually. Given the slow growth of the species and the current healthy status of the stock, five years is an appropriate time scale for assessment. The Science Response Report will include updates to key information including the time series of catch, effort, footprint, catch per unit effort, and results of the spatial production models. Bycatch from the fishery will be reviewed annually by DFO Science and included in the Science Response reports if there is a substantial change in bycatch trends (i.e., if values are outside of the range previously observed in the fishery). An assessment can be triggered in an update year. Triggers include the following situations: if there are issues with the spatial production model, if the median biomass estimate of the fishable biomass for all spatial assessment areas combined is approaching the Cautious Zone, and/or if there is a 30% increase in annual fishery footprint. A new framework will be triggered when there is significant new information that would change the assessment approach, e.g., new survey information or detailed habitat information.

Sources of Uncertainty

If fishing becomes more efficient, catchability would likely increase over time, leading to a bias in CPUE. An increase in efficiency and catchability over the life of the fishery could mask a flat or negative trend in biomass as positive. The licence holder has reported increasing fishing efficiencies.

The Spatial Production Model model parameters (r and K) are partly confounded and potentially biased because high r and low K give the model more flexibility to fit the data. If r is too high and K is too low, reference points are likely to be overly optimistic (higher FMSY and lower B_{MSY}). Additionally, subjectivity was necessary for the analysis when defining the threshold for consideration as a ‘fished area’. Here 30 pings per km2 cumulated between 2004 and 2017 was used as the threshold. Whereas 30 pings seems a reasonable proxy of fishing activity, a more rigorous analysis should be conducted to test the sensitivity of the SPM to this parameter.

The amount of biomass beyond the extent of the fished area used in this analysis remains unknown. Exploratory fishing and significant investment in advanced technology (e.g., multibeam) has been used by the licence holder to discover additional areas of exploitable clam biomass. Areas of highly suitable habitat have a high degree of overlap with areas considered ‘fished’ in this analysis. Whether or not there is a large amount of clam biomass present in unfished areas and, therefore, not considered or missed by this analysis is still disputed by some. Fishery independent surveys covering entire stock area have been recommended to elucidate this issue.

CONCLUSIONS AND ADVICE

Setting potential harvest levels based on the estimated biomass in the fished areas would increase the likelihood that the areas that have supported a commercial fishery since 1986 are not depleted. Setting potential harvest levels based on an estimated biomass for the full Bank could increase the likelihood that these historically fished areas would be depleted. By focussing the assessment on a stock definition of exploited biomass, it is possible to measure the effect of the fishery on the fished biomass. There is little information available for areas that have not previously supported fisheries besides the 2010 survey and biomass estimates that were based on information that was highly uncertain and unquantified. A highly precautionary assumption would be to assume that dredge efficiency is 100% (q = 1); however, the production model permits the uncertainties in CPUE and the estimates of dredge efficiency to be quantified and propagated into the biomass estimates.

Maximum sustainable yield (MSY) reference points were calculated from the surplus production model with estimates of fishing mortality that yield MSY (F_{MSY}) near 0.09; however, phase plots (Figure 9) indicate that catch rates tend to decline when F is greater than 0.5 F_{MSY}. Despite how the spatial assessment areas are divided, there is considerable risk associated with setting TAC recommendations based on biomass estimates that result from areal expansion of Surfclam density (g/m^2) to areas that have not previously been fished. In addition, exploitation rates near the estimates of F_{MSY} are more risky than alternative F reference levels that are below F_{MSY}.

The Banquereau Arctic Surfclam stock is considered to be in the healthy zone, as the median modelled biomass estimates are above all of the biomass reference levels (LRP, USR, $CPUE_{70}$) for all the areas (Figure 6, 7; Table 3). However, the CPUE indicates biomass has decreased since the last assessment in 2010, particularly in area 5 (Figure 7). It is recommended biomass estimates generated from the SPM model be used, in order to keep the exploitation rate for the fished areas within the reference levels. Of the three potential F removal references, F_{MSY} is considered to have the highest associated risk since declines in CPUE have been observed at significantly lower F levels. The 0.5 F_{MSY} (close to 0.5M) level would result in TAC that is comparable to the current TAC for Banquereau (24,000 t) while the low risk F level would result in much lower TACs when it is applied to the fished area biomasses (Table 4).

It was recommended that for a future analysis, the 2004 and 2010 survey data be combined with habitat suitability information to inform a biomass estimate for the full Bank.

Table 3. Probability that biomass is greater than the limit reference point (LRP), upper stock reference (USR), and a CPUE of 70 g/m² ($CPUE_{70}$) for each proposed assessment area (1-5) and for total area.

Area	LPR	USR	$CPUE_{70}$
1	>0.99	>0.99	0.89
2	>0.99	>0.99	0.93
3	>0.99	>0.99	0.94
4	>0.99	>0.99	0.87
5	>0.99	>0.99	0.96
Total	>0.99	>0.99	0.96

Table 4. Total Allowable Catches (TAC) in tonnes for proposed removal reference levels (F) for proposed assessment areas (1-5) calculated using the 2016 biomass estimates from spatial production model.

Removal Reference (F)	Area 1	Area 2	Area 3	Area 4	Area 5	Total
$0.5F_{MSY}$ (0.045)	3,700	6,159	5,847	5,847	2,844	20,943
0.33M (0.026)	2,158	3,593	3,410	3,410	1,659	12,215

SOURCES OF INFORMATION

This Science Advisory Report is from the April 20-21, 2017, Arctic Surfclam Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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MPO. 2017. Évaluation du stock de mactres de Stimpson (Mactromeris polynyma) du Banquereau en 2016. Secr. can. de consult. sci. du MPO, Avis sci. 2017/047.