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Precautionary Approach Reference Points for Arctic Surfclams (*Mactromeris polynyma*)

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Foreword

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ABSTRACT

Reference points for the Arctic Surfclam (*Mactromeris polynyma*) stocks on Banquereau and Grand Bank are proposed. The approach uses historic average recruitment and a Biomass per Recruit analysis to estimate B_0 and B_{MSY}. This is a relatively recent fishery and so biomass has never been reduced to low levels. With no contrast in biomass to fit models, the default Upper Stock and Lower Reference Points are used.

Points de référence de l'approche de précaution pour la mactre de Stimpson (*Mactromeris polynyma*)

RÉSUMÉ

On propose des points de référence pour les stocks de mactre de Stimpson (*Mactromeris polynyma*) sur le banc Banquereau et les Grands Bancs. L'approche utilise le recrutement moyen historique et une analyse de la biomasse par recrue pour estimer B_0 et B_{MSY}. Il s'agit d'une pêche relativement récente, la biomasse n'a donc jamais été réduite à de faibles niveaux. Étant donné l'absence de contraste dans la biomasse pour adapter les modèles, on utilise les points de référence supérieur et inférieur du stock.

BACKGROUND

The Arctic Surfclam fishery is a relatively recent fishery, having started in 1986. It harvests Arctic Surfclams on Banquereau and Grand Bank using freezer-processor vessels equipped with hydraulic dredges. There are licences for four vessels, but currently (2012) only two are active.

Hydraulic dredges are bottom contact gear that have an immediate impact on the substrate and benthic organisms, disturbing the sediment to at least 20 cm. They use a series of water jets on the front of the dredge to liquefy the substrate, which then passes through the inclined bars of the “knife”. Clams and other objects too large to pass though the bars ride up the “knife” into the cage portion of the dredge. This gear can only be used on sand as it is damaged by rocky substrates and sinks into muddy ones. The target species lives on fairly mobile, well sorted sand bottoms that are periodically disturbed by storms. Studies on the impacts of this gear on Banquereau indicate that, with the exception of the large bivalves that are removed by the dredge, the community recovers by three years following dredging. In shallow areas the tracks are not detectable the following year, but in a study site at 70 m depth, tracks were still detectable with sidescan sonar ten years after dredging. The fishery currently takes place in 45 to 65 m depth. The total impact of the clam fishery is usually ranked lower than other fisheries due to its current small footprint.

Stock assessments for offshore clams currently use efficiency-corrected survey biomass of commercial sized clams as the fishable biomass. There is still a lot of uncertainty in this, as there have been few surveys, each of which has used a different vessel and dredge. The efficiency correction for the latest (2006-2009) Grand Bank survey is unknown, and the efficiency estimate for the 2010 Banquereau survey has a large confidence interval.

TARGET EXPLOTATION AND BIOMASS REFERENCES

Due to the uncertainties about population dynamics and the fact that Arctic Surfclams are a long lived (60+ years), slow growing species, the 2007 framework and assessment recommended a conservative target F of 0.33M be used for this fishery. This is loosely based on the Maximum Constant Yield (MCY) approach used for non-monitored fisheries in New Zealand (Annala 1993, Caddy 1998, Zhang 1999), but would be considered at the high end of the recommended range of an MCY approach, as there would always be some level of monitoring for Canadian fisheries. This F level was used in the 2007 and 2011 Banquereau and the 2010 Grand Bank Arctic Surfclam assessments (Roddick et al. 2007, 2011, 2012).

With $F_{0.33M}$ as the Fishing Mortality Target, the biomass level corresponding to fishing at this level can be estimated using the Biomass per Recruit model. The Biomass per Recruit model used for Banquereau and Grand Bank includes a 15% mortality rate on small clams that pass through the dredge (Roddick et al. 2012).

The Biomass per Recruit analysis for Banquereau Arctic Surfclams indicates that fishing at $F_{0.33M}$ would reduce the fishable biomass per recruit to 71% of what it would be with no fishing (Figure 1). This indicates that the Biomass Target corresponding to $F_{0.33M}$ should be $0.71B_0$. for Banquereau. Using the same approach the Biomass Target for Grand Bank would be $0.74B_0$.

These are higher than the Marine Stewardship Council (MSC) default target reference point of $0.4B_0$, and would maintain the biomass at a higher level. The trade-off is more stable landings, a higher Catch per Unit Effort (CPUE), smaller footprint and less habitat impact, against the foregone landings that could be achieved with a more aggressive target.

The last two fishable biomass estimates from surveys on Banquereau have been 1,462,097 t in 2004 and 1,150,585 t in 2010. These estimates come from surveys using different vessels and gear and are thus not directly comparable. The population is felt to still be near B_0, and thus these estimates can be considered as approximate estimates of B_0 when B_0 is in terms of fishable biomass. The survey biomass estimate for Grand Bank is 1,140,682 t, but this assumes an efficiency estimate of 1 for the survey gear, and thus is an underestimate of the true fishable biomass.

Another approach to estimate values of B_0 and B_{MSY} is to take the estimated average recruitment and a Biomass per Recruit analysis. The average recruitment times the fishable Biomass per Recruit with no fishing gives an estimate of B_0, while average recruitment times the Biomass per Recruit when fishing at $F_{0.33M}$ gives an estimate of B_{MSY}. The last Banquereau assessment estimated average recruitment to Banquereau as 493 million clams at age 25 per year, and natural mortality of 0.08 (Roddick et al. 2012). Recruitment at age 0 is then $493.0/e^{(-.08*25)}$ = 3,642.8 million clams. Multiplying by the fishable biomass per recruit at F=0 and $F_{0.33M}$ gives 1,431,426 t as B_0 and 1,015,058 t as B_{MSY} (Table 1). The estimate for average recruitment uses the same data as the survey biomass estimate, i.e. numbers from the 2010 survey corrected for dredge efficiency.

The Grand Bank analysis is complicated by the fact that the area was surveyed with three surveys over four years with different vessel and gear combinations each year. There is no efficiency estimate available for the surveys. The efficiency estimate is not a large factor in determining the current biomass relative to B_0, as with the approach used, it would scale both the survey biomass estimate and the estimate of average recruitment. This means that although the values would scale up, their position in relation to one another should stay the same. The estimated average recruitment at age 25 from each survey and the natural mortality rate was used to calculate the average numbers at age zero for each survey. An estimate of the total number of age zero clams, weighted by the number of tows per survey, for the area towed was then scaled to the survey area. This produced an estimate of 4,948 million clams age zero per year. Using the fishable biomass per recruit for Grand Bank (Table 2) produces estimates of 947,991 t for B_0 and 703,065 t for $B_{0.33M}$. The survey biomass estimate of 1,140,682 t is thus 20% higher than the estimate of B_0 calculated from average recruitment. This difference is probably attributable to the combining of surveys with different vessels and gear, but it could simply be that the present biomass is above the long term average. It does indicate that with the low level of exploitation it has experienced, the biomass on Grand Bank is still near the virgin biomass level.

The problem with a Biomass per Recruit approach is that it does not account for any Stock-Recruit relationship. There has been no Stock-Recruit relationship established for Arctic Surfclams, and since there is no contrast in the fishery or survey data to date, we cannot fit one to existing data. For bivalve populations, there is usually little effect of a Stock-Recruit relationship until the biomass gets very low. Bivalves, being broadcast spawners, produce large numbers of eggs per individual. This means that at higher levels of Spawning Stock Biomass (SSB) favourable environmental conditions are more important than stock size in determining recruitment levels. It is likely that there would be little effect of a Stock-Recruit relationship at the current target levels for Arctic Surfclams.

CURRENT STATUS

The average fishing mortality rate for 2004 to 2010 on Banquereau was estimated to be F=0.016, well below F_{MSY} = 0.0264. The Banquereau population biomass is estimated to be still close to B_0, and with a conservative exploitation rate it will take a long time to reduce it to B_{MSY}. From the 2010 survey, the biomass estimates are B_{MSY} = 1,015,058 t, $B_{current}$ = 1,150,585 t and B_0 = 1,431,426 t. These are in terms of fishable biomass as they are based on the surveys. The 2004 survey produced a higher biomass estimate and so these values would all be shifted higher but the pattern would be the same.

The Grand Bank population is estimated to be currently above B_0, but there are uncertainties due to the use of different vessel and gear combinations for the surveys. The average Fishing Mortality on Grand Bank for 2004 to 2010 is F=0.002 well below F_{MSY} = 0.0264.

The Arctic Surfclam stocks are, therefore, in the healthy zone and are expected to remain there in the medium to long term in the absence of a large increase in fishing or natural mortality.

LIMIT REFERENCE POINT AND UPPER STOCK REFERENCES

This fishery is relatively new and has not had a high exploitation rate to date. The species is long lived and there are a large number of year classes in the catch. This means we do not know how the stock or ecosystem will react to the stock being fished down to low levels. The life history characteristics are all we can use to guide assumptions. As we cannot say at what level recovery would be impaired we cannot recommend Limit Reference Point (LRP) and Upper Stock Reference (USR) levels any better than the defaults of USR = 80% B_{MSY} and LRP = 40% B_{MSY}.

SECONDARY INDICATORS

Secondary indicators for this fishery are not proposed to help in determining where the stock is in relation to the LRP and USR points, but to help in monitoring the status of the stocks between surveys. Surveys are not conducted on an annual basis for the Arctic Surfclam stocks and so secondary indicators would be used to monitor for a change in stock status. Proposed indicators and triggers are shown for Banquereau.

CPUE is one of the most common indicators of biomass status. It was evaluated during the 2007 framework meeting and found not to be a good indicator of stock status due to the sedentary nature of surfclams and the ability of the fleet to move around. Improvements have been made since then, but the spatial distribution of effort shows that the fleet still moves around to maintain their catch rate. Figure 1 shows the CPUE trends for the last four vessels active in the Banquereau fishery. CPUE has increased the last few years, mainly due to a recruitment pulse entering the fishery, but some of the increase would be due to technological and knowledge improvements over time. The recent low point in CPUE was 60 g/m^2 in 2002. This can be considered a level that would trigger a closer look at the status of the stock, but it was a level that was not felt to indicate a depleted stock at the time, and from which the fishery recovered with no intervention.

Another secondary indicator is the **footprint of the fishery**. As densities decline, effort is increased to maintain landings, and there is more searching for patches of higher density. The historic high for the footprint of the fishery on Banquereau is 253 km^2 in 1999 (Table 3), but this was during the 1993-2006 period when three vessels were active in the fishery. Taking two-thirds of this to match the current two vessel fleet, gives 168.7 km^2, which is almost double the average footprint for the last three years when there have only been two vessels active. Once again the 1999 level was not felt to indicate any problems with the stock at the time, but can be used as a level that would trigger a closer look at the status of the stock if it were reached again.

Since it is felt that the stock is currently lightly exploited and the catch contains a large number of age classes, a third indicator of stock status is the **abundance of older clams in the catch** (Table 4 and Figure 3). A decrease in older clams is expected as the age structure adjusts to the increased mortality due to fishing. Using the Biomass per Recruit model and commercial selectivity, fishing at $F_{0.33M}$ would result in an average age distribution with 0.998% of the clams over age 60. The growth of Arctic Surfclams on Banquereau levels off after age 35 and so any length grouping over 100 mm can contain clams from 10 to 80 years old. The selection of a size representing older clams, therefore, becomes an arbitrary grouping and will contain some younger clams as well. From the length distribution from the catch shown in Figure 3, a size of 120 mm was selected as representing an appropriate round number for the upper tail of the size distribution. The historic low for the percentage of clams over 120 mm was 1.71% in 2005 (Table 4). Once again the historic low was not a period when the stock was considered to be in a depleted state, so this trigger would result in a closer look at the status of the stock. Since there are recruitment “patches” of surfclams, the fishery has some ability to fish for certain size ranges by concentrating on appropriate “patches” of age classes. This means that a change in preferred market size could change the spatial distribution of effort and the size distribution of the catch without any change in population size/age structure.

Grand Bank has had low levels of exploitation throughout its history, and so if fishing increased to near target exploitation rates the triggers based on historical values would probably have to be revised. The Banquereau trigger values could initially be used as a guide.

If these secondary indicators initiated a review that determined that there was reason for concern about the health of the stock the result could be immediate management measures, or a survey to confirm the status of the stock.

REMOVAL RATE IN CAUTIOUS ZONE

Once the stock has been determined to have crossed from the healthy to the cautious zone a management response is triggered. This is typically a reduction in fishing mortality that increases as the biomass of the stock decreases. This can be a linear reduction from the target F at the USR to no directed fishing at the LRP, or a non-linear response that can also take different shapes depending on the direction of recent changes in biomass. For bivalves, the response could depend on evidence of pre-recruit year classes. If the stock is low but there is evidence of above average pre-recruits about to enter the fishery there is less concern than if the evidence is for below average recruitment. There are no other sources of fishing mortality for this stock.

DISCUSSION

Some advantages of the biomass per recruit approach are that it does not require a time series of data or periods of fishing at different levels of biomass. If the survey biomass estimates are biased, the bias also applies to the estimate of average recruitment levels. The information coming out of the analysis is the relative positions of the current and target biomass so a bias will move the values in the same direction but their relative positions should remain the same.

There is no Stock-Recruit relationship assumed in this approach. Historic recruitment levels are used to estimate average recruitment levels, so if the biomass were fished down and the stock responded with a change in recruitment, the historic recruitment pattern will no longer apply. Most bivalves have a high fecundity, so unless the stock is severely depleted, environmental factors have a greater effect on recruitment than spawning stock biomass. Since the objective of managing the fishery is to avoid depleting the resource, the lack of a Stock-Recruit relationship in the approach should not be a problem.

Modeling of the harvest control rules and reference points still has to be conducted to test the robustness of the system. Growth rate, natural mortality and maturity are well estimated for Banquereau and Grand Bank. The biggest uncertainty is the recruitment process. A variety of recruitment scenarios should be part of this analysis, as well as a variety of survey frequencies. Models with a spatial component would allow the examination of the effects of spatial distribution of effort. Fisheries and Oceans Canada does not presently have an active research and assessment program for Arctic Surfclams. It is likely that survey frequency will be decadal or longer, especially if there are no indications of declining abundance. A robust management system with secondary indicators used between surveys will be required.

REFERENCES

Annala, J.H. 1993. Fishery assessment approaches in New Zealand's ITQ system. *In* Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations, 21-24 October 1992. Edited by G. Kruse. Anchorage, Alaska. pp. 791-806.

Caddy, J.F. 1998. A short review of precautionary reference points and some proposals for their use in data-poor situations. FAO Fish. Tech. Pap. 379. 30 p.

Roddick, D., R. Kilada, and K. Mombourquette. 2007. Survey for Arctic Surfclams (*Mactromeris polynyma*) on Banquereau, 2004. DFO Can. Sci. Adv. Sec. Res. Doc. 2007/035. 39 p.

Roddick, D., J. Brading, L. Carrigan, T. Davignon-Burton, S. Graham, and C. McEwen. 2011. Assessment of the Arctic Surfclam (*Mactromeris polynyma*) stock on Grand Bank. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/052. iv + 54 p.

Roddick, D., J. Brading, L. Carrigan, T. Davignon-Burton, S. Graham, and C. McEwen. 2012. Assessment of the Arctic Surfclam (*Mactromeris polynyma*) stock on Banquereau in 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/050. iii + 59 p.

Zhang, Z.Y. 1999. A review of assessment tools for data-limited fisheries. Can. Stock. Assess. Sec. Res. Doc. 99/194. 47 p.

Table 1. Biomass per recruit table for Banquereau Arctic Surfclams. Removals include an incidental mortality of 15% on small clams. SSB is spawning stock biomass estimated using the maturity curve for Banquereau, and Fish Bio is fishable biomass estimated with the selectivity curve for commercial gear. The Biomass per recruit for $F_{0.33M}$, $F_{0.1}$ and F_{MAX} as their proportion of F_0 are show, as well as the estimated Biomass for B_0 and $B_{0.33M}$ estimated using the average recruitment in relation to the survey biomass estimate ($B_{Current}$).

F	Yield	Removals	Biomass	SSB	Fish Bio	
0.000	0.000	0.000	682.557	588.677	392.947	
0.001	0.372	0.414	674.910	581.188	387.312	
0.021	5.956	6.720	550.742	460.078	297.262	
0.0264	7.006	7.936	524.515	434.644	278.648	$F_{0.33M}$
0.041	9.199	10.533	464.452	376.661	236.688	
0.061	11.130	12.929	401.109	316.023	193.645	
0.08095	12.273	14.461	352.787	270.248	161.851	$F_{0.1}$
0.081	12.275	14.465	352.681	270.149	161.782	
0.101	12.930	15.453	314.475	234.358	137.432	
0.121	13.269	16.079	283.571	205.742	118.343	
0.141	13.397	16.459	258.062	182.403	103.064	
0.149	13.406	16.562	248.848	174.047	97.663	F_{MAX}
0.161	13.384	16.668	236.647	163.052	90.618	
0.181	13.276	16.755	218.414	146.782	80.330	
0.201	13.102	16.756	202.699	132.939	71.716	
0.221	12.884	16.695	189.015	121.040	64.425	
0.241	12.637	16.589	176.989	110.720	58.193	
0.261	12.371	16.450	166.336	101.699	52.820	
0.281	12.094	16.287	156.834	93.758	48.154	
0.301	11.811	16.107	148.303	86.725	44.073	
0.321	11.525	15.915	140.602	80.460	40.482	
0.341	11.241	15.716	133.615	74.852	37.304	
0.361	10.959	15.512	127.247	69.809	34.478	
0.381	10.682	15.305	121.418	65.254	31.954	
0.401	10.409	15.097	116.062	61.126	29.688	
0.421	10.143	14.889	111.125	57.370	27.648	
0.441	9.884	14.682	106.559	53.942	25.803	
0.461	9.631	14.477	102.323	50.804	24.130	
0.481	9.385	14.275	98.383	47.924	22.608	
0.501	9.147	14.076	94.710	45.273	21.219	
0.521	8.915	13.880	91.276	42.828	19.948	
0.541	8.690	13.688	88.059	40.567	18.782	
0.561	8.472	13.499	85.040	38.473	17.709	
0.581	8.261	13.314	82.201	36.528	16.721	
0.601	8.056	13.133	79.527	34.720	15.809	
$B_{0.33M}$			0.8081	0.6223	0.7416	
$B_{0.1}$	As fraction of B_0		0.5338	0.2462	0.4031	
B_{MAX}			0.3997	0.1350	0.2581	

B_0	$B_{Current}$	$B_{0.33M}$
1,431,426 t	1,150,585 t	1,015,058 t

Table 2. Biomass per recruit table for Grand Bank Arctic Surfclams. Removals include an incidental mortality of 15% on small clams. SSB is spawning stock biomass estimated using the maturity curve for Banquereau, and Fish Bio is fishable biomass estimated with the selectivity curve for commercial gear. The Biomass per recruit for $F_{0.33M}$, $F_{0.1}$ and F_{MAX} as their proportion of F_0 are show, as well as the estimated Biomass for B_0 and $B_{0.33M}$ estimated using the average recruitment in relation to the survey biomass estimate ($B_{Current}$).

F	Yield	Removals	Biomass	SSB	Fish Bio	
0.0000	0.0000	0.0000	459.365	97.780	191.579	
0.0010	0.1818	0.2201	455.272	95.881	189.226	
0.0210	3.0176	3.7289	386.404	66.587	150.410	
0.0264	3.5783	4.4456	371.228	60.846	142.082	$F_{0.33M}$
0.0410	4.7876	6.0343	335.549	48.430	122.879	
0.0610	5.9122	7.5973	296.397	36.610	102.508	
0.0810	6.6262	8.6776	265.284	28.594	86.936	
0.0965	6.9882	9.2846	245.213	24.069	77.227	$F_{0.1}$
0.1010	7.0691	9.4311	239.937	22.963	74.723	
0.1210	7.3280	9.9566	218.869	18.881	64.941	
0.1410	7.4595	10.3187	201.068	15.841	56.969	
0.1610	7.5013	10.5616	185.819	13.519	50.376	
0.1642	7.5016	10.5912	183.607	13.203	49.440	F_{MAX}
0.1810	7.4796	10.7159	172.602	11.707	44.855	
0.2010	7.4124	10.8037	161.033	10.265	40.181	
0.2210	7.3129	10.8409	150.818	9.098	36.187	
0.2410	7.1905	10.8395	141.729	8.137	32.744	
0.2610	7.0520	10.8082	133.589	7.336	29.756	
0.2810	6.9026	10.7540	126.256	6.660	27.143	
0.3010	6.7461	10.6820	119.614	6.083	24.846	
0.3210	6.5854	10.5963	113.569	5.585	22.816	
0.3410	6.4226	10.5001	108.045	5.153	21.012	
0.3610	6.2594	10.3959	102.976	4.773	19.403	
0.3810	6.0970	10.2856	98.310	4.439	17.960	
0.4010	5.9363	10.1710	93.999	4.141	16.663	
0.4210	5.7780	10.0531	90.005	3.876	15.492	
0.4410	5.6225	9.9332	86.294	3.637	14.432	
0.4610	5.4704	9.8119	82.839	3.422	13.469	
0.4810	5.3217	9.6900	79.612	3.227	12.592	
0.5010	5.1768	9.5680	76.594	3.050	11.791	
0.5210	5.0356	9.4463	73.764	2.887	11.058	
0.5410	4.8983	9.3254	71.106	2.739	10.385	
0.5610	4.7649	9.2054	68.604	2.602	9.767	
0.5810	4.6353	9.0866	66.247	2.477	9.197	
0.6010	4.5096	8.9692	64.021	2.360	8.670	
$B_{0.33M}$			0.8081	0.6223	0.7416	
$B_{0.1}$	As proportion of B_0		0.5338	0.2462	0.4031	
B_{MAX}			0.3997	0.1350	0.2581	

B_0	$B_{Current}$	$B_{0.33M}$
947,991 t	1,140,682 t	703,065 t

Table 3. Area dredged and Footprint of the fishery by year. Footprint is area dredged from logbooks as the % of the area within the 100 m contour on Banquereau. It does not account for overlapping tows.

Year	Area Dredged (k^2)	% Area
1986	1.1	0.01
1987	16.1	0.16
1988	24.2	0.24
1989	84.5	0.84
1990	68.2	0.67
1991	9.8	0.10
1992	0.0	0.00
1993	0.9	0.01
1994	39.5	0.39
1995	84.0	0.83
1996	153.7	1.52
1997	155.5	1.54
1998	237.1	2.35
1999	253.1	2.50
2000	233.2	2.31
2001	159.0	1.57
2002	149.6	1.48
2003	147.2	1.46
2004	149.9	1.48
2005	141.5	1.40
2006	116.8	1.16
2007	104.2	1.03
2008	83.4	0.82
2009	97.9	0.97
2010	86.6	0.86
Total	2,597.0	25.69

Table 4. Percentage of clams greater than 120 mm shell length from commercial on-board sampling of the catch by year.

Year	n	Percent large clams
1999	4,203	9.06
2000	4,169	5.59
2001	1,756	7.46
2002	3,670	8.09
2003	3,511	4.53
2004	6,033	1.92
2005	4,380	1.71
2006	2,362	5.33
2007	6,147	8.77
2008	7,793	4.53
2009	23,806	10.20
2010	15,679	5.41
2011	916	8.19

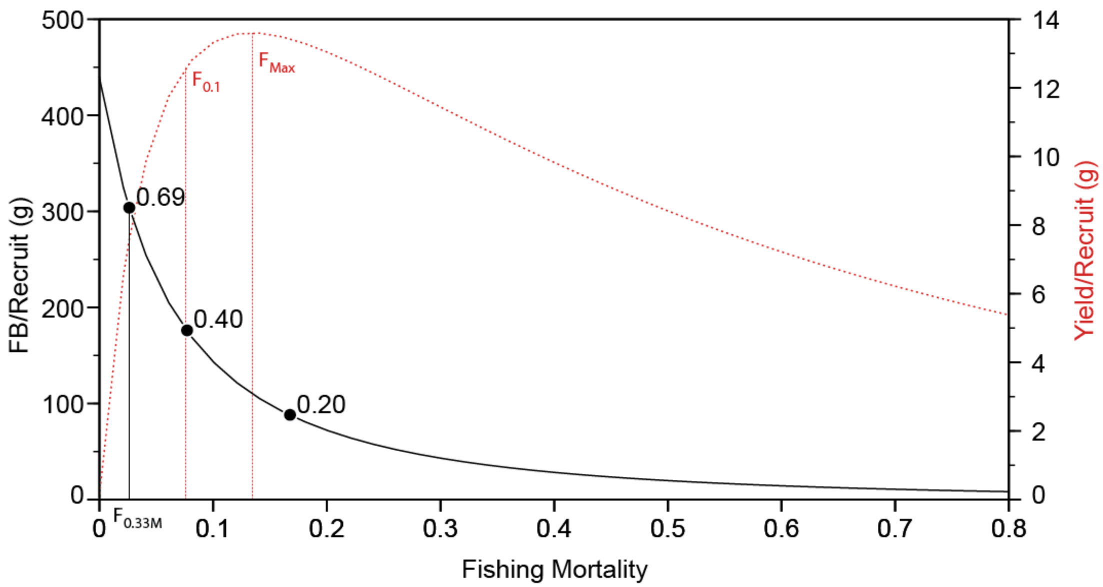

Figure 1. Yield and Fishable Biomass per Recruit for Arctic Surfclams on Banquereau, showing some common and the proposed Fishing Mortality reference values.

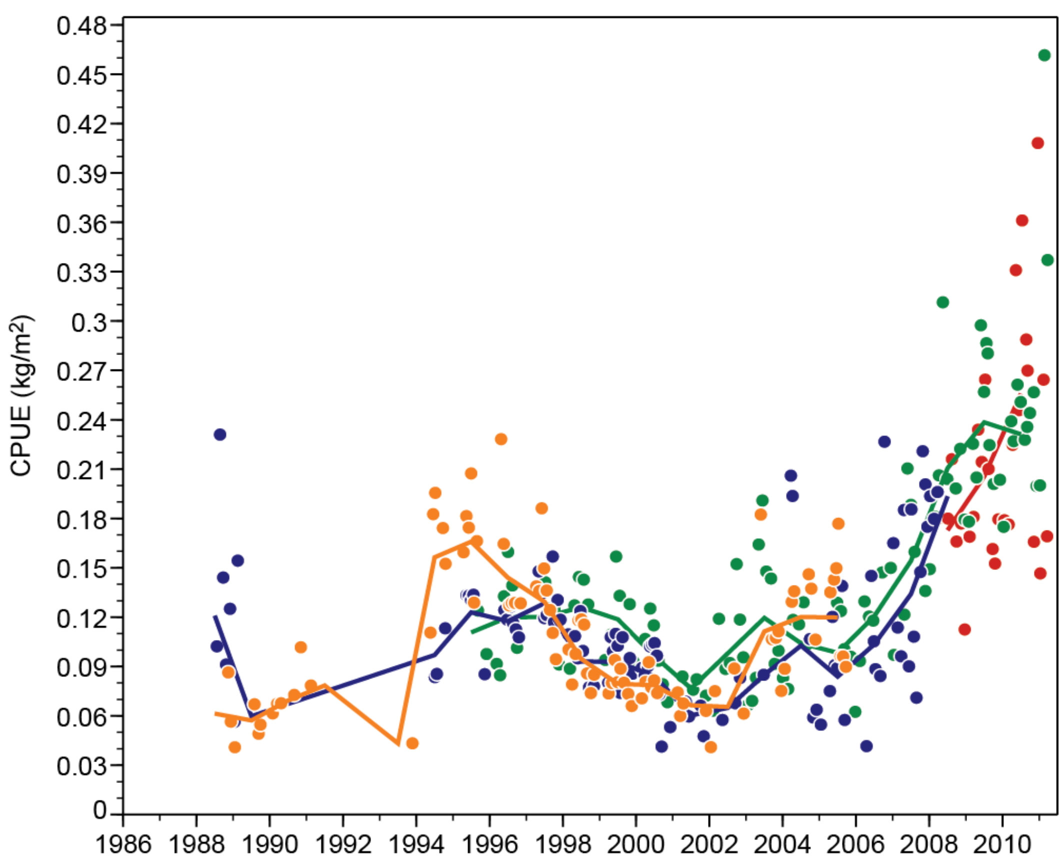

Figure 2. CPUE for the last four vessels active in the Arctic Surfclam fisher on Banquereau. Symbols are coloured by vessel, dots are CPUE by sub-trip, and lines connect yearly averages for vessels.

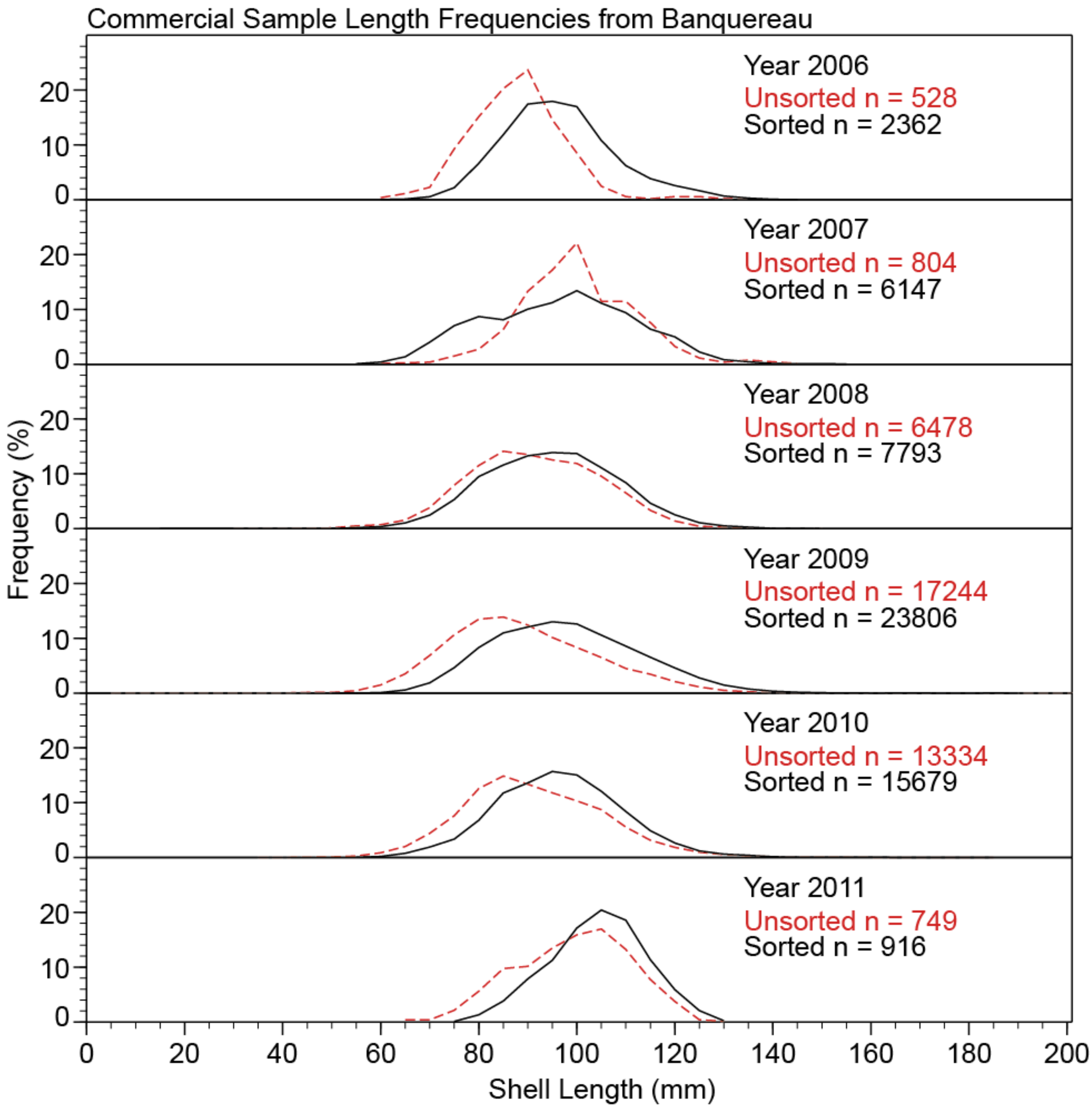

Figure 3. Length Frequencies from commercial on-board sampling program.

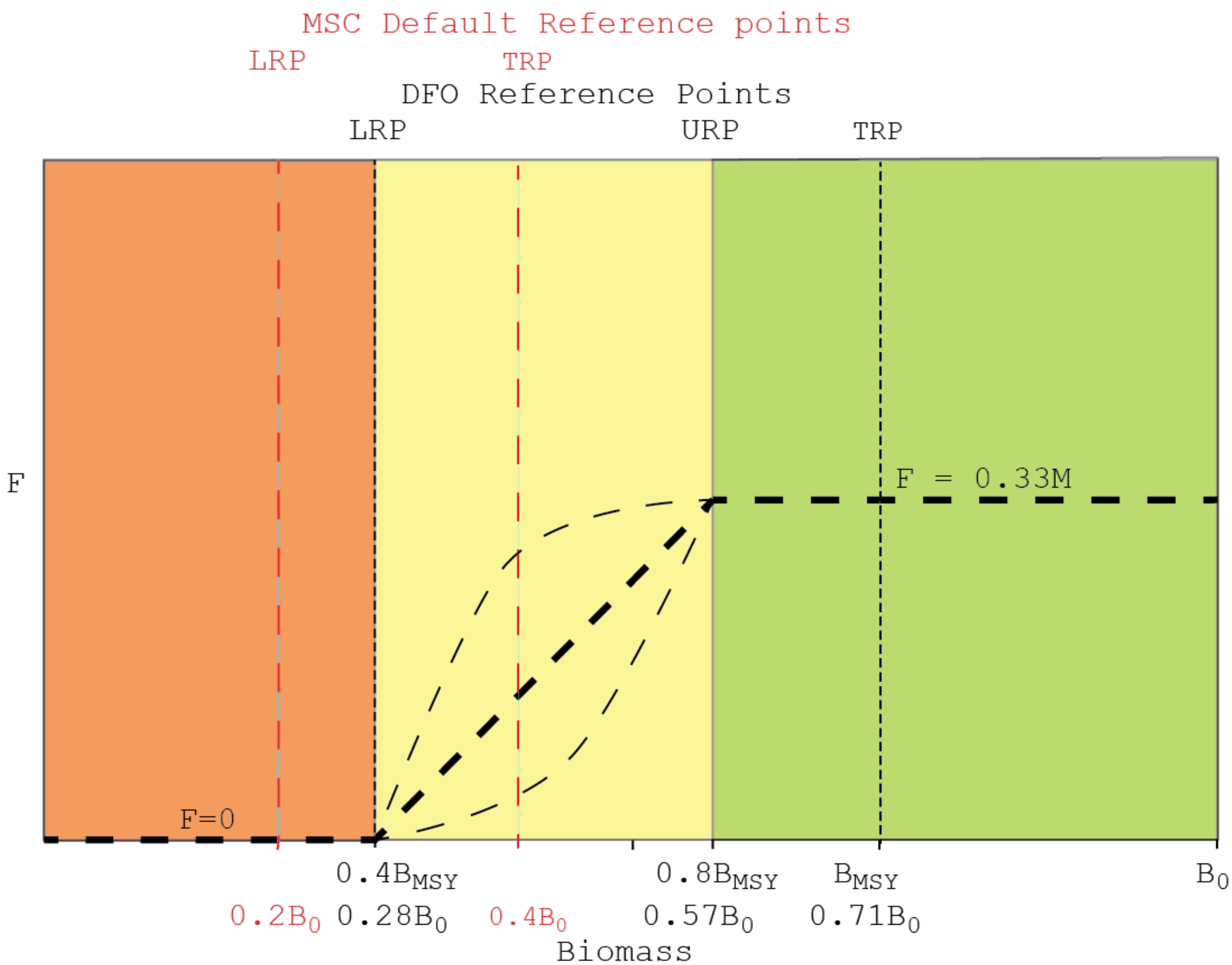

Figure 4. Diagram showing target fishing mortalities and biomass levels and the corresponding LRP and USR points for Banquereau Arctic Surfclams. The MSC default values are shown for comparison. Alternate trajectories are displayed for when the biomass is in the cautious zone.