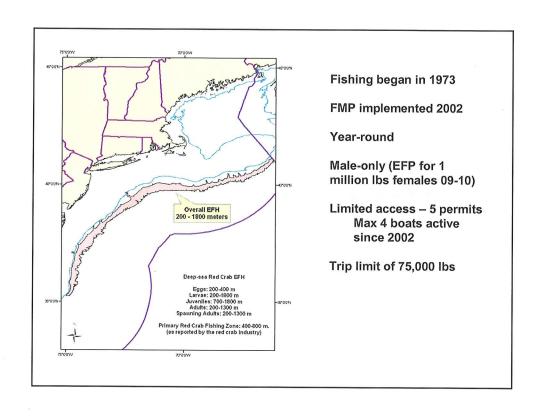
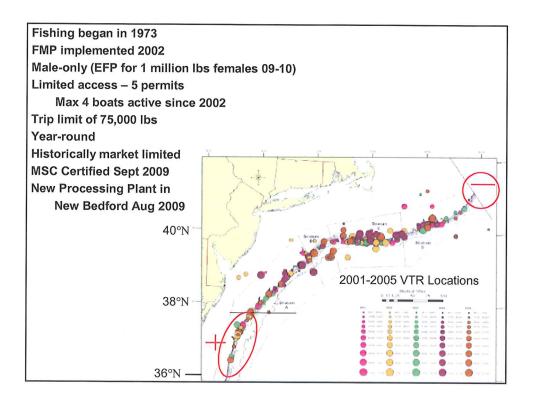
Red Crab PDT MSY Proxy Reevaluation

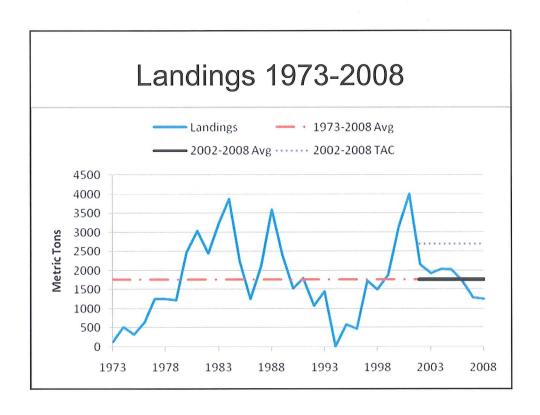
March 16, 2010

Summary

- The PDT agrees with the recommendation of the DPSWG for "a catch limit that mimics both recent and long term mean annual landings..."
- The PDT agrees with the Review Panel preference for the DCAC model, but believes that the sustainable yield estimates should be adjusted to reflect the expected difference between DCAC results and MSY.
- The PDT developed additional information related to concerns expressed by DPSWG







	ai vo	y / \i)PSV	nass VG)	LO	tiiiia		
		Males			Females			Total	
Year									
Size Groups	Biomass	SE	CV	Biomass	SE	CV	Biomass	SE	CV
(mm CW)	(mt)	(mt)	(mt)	(mt)	(mt)	(mt)			
1974									
90+	29,991	6,298	0.21	15,654	3,719	0.24	45,645	7,314	0.16
114+	23,794	4.303	0.18	2,106	433	0.21	25,900	4,325	0.17
Fishable	30,302	34,300	0 mt	Α	NA	NA	NA	NA	NA
All	32,190	5,001	0.16	20,674	5,221	0.25	52,864	7,230	0.14
2003 to 2005									
90+	38,220	4,298	0.11	55,279	7,033	0.13	93,499	8,242	0.09
114	13,770	1,334	0.1	5,224	576	0.11	18,994	1,453	0.08
Fishable	36,247	4,612	0.13	NA	NA	NA	NA	NA	NA
All	56,443	4,646	0.08	74,689	10,102	0.14	131,132	11,119	0.08

 Figure 5- Trip weights for butchered crabs landed by the Fall River, MA fleet from 1978 through 1990. (Industry data published with permission of the vessel owners.)

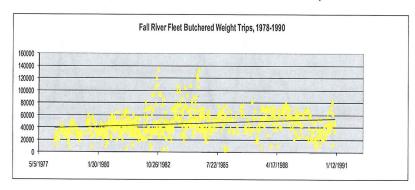


Figure 6- Live equivalent crab trip weights landed by the Fall River, MA fleet from 1978 through 1990 and 2000 through 2004. (Industry data published with permission of the vessel owners.)

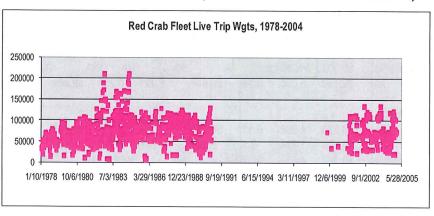
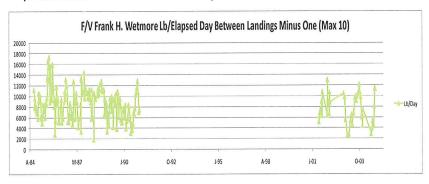


 Figure 7- Pounds per day between landings (minus one with a maximum of ten) for the F/V Frank H. Wetmore for 1984 through 1991 and 2001 through 2004. (Industry data published with permission of the vessel owner.)



Risk Policy

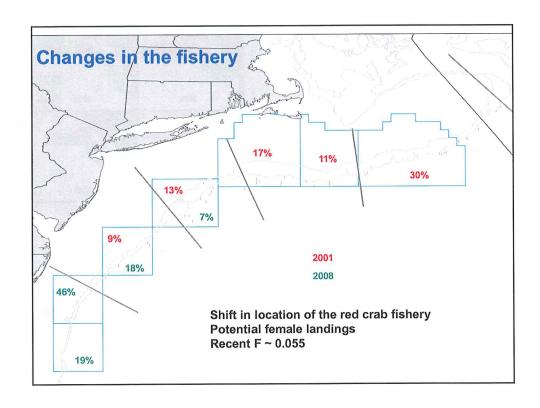
- "The scope of work may not request reviewers to provide advice on scientific policy (e.g., amount of uncertainty that is acceptable or amount of precaution used in an analysis). Such policy considerations are in the purview of the Secretary and the Councils." NS 2 Guidelines
- "Determining the acceptable level of risk of overfishing that results from scientific uncertainty is the policy issue. The SSC must recommend an ABC to the Council after the Council advises the SSC what would be the acceptable probability that a catch equal to the ABC would result in overfishing." NS 1 Guidelines

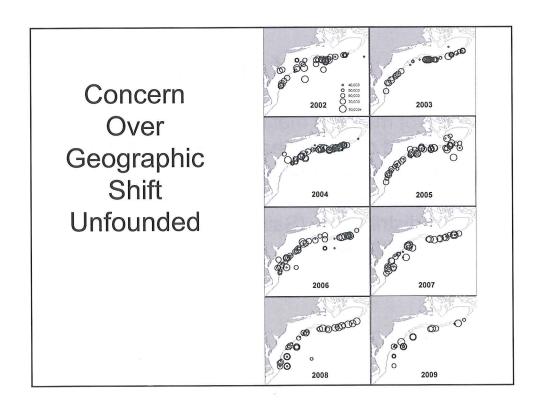
DPSWG Problematic Conclusions

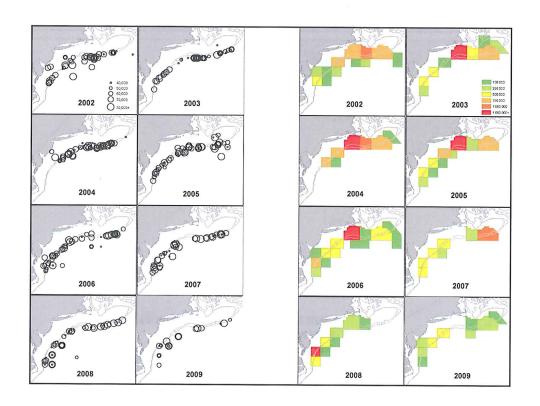
<u>"assumptions that reductions in the size structure of landings that have been observed indicate that previous higher landings were not at a sustainable MSY levels as had been previously assumed."</u>

DPSWG Problematic Conclusions

- The [Review] Panel concluded that estimates of MSY in the male only fishery of 1700-1900 mt represent the best available scientific information, based on the congruence of average landings and results from the DCAC model.
- Zero depletion DELTA assumption
- DCAC model results 50-72% of MSY







Size Ratio of Mating Pairs

 Size of males in mating snow crab pairs changed over the years in relation to the passing of troughs and waves of recruitment with corresponding changes in size distribution. (Sainte-Marie, Sevigny and Smith 1996)

Size of Males in Mating Pairs

- Elner (1987) observed three mating pairs of *C. quinquedens* in captivity in which males were 10.2, 15.1, and 20.6 % larger than the females. These females were later found to contain sperm masses.
- Zheng and Kruse (2003) point out that "large oldshell mature males outcompete small newshell males in mating with females" in snow and Tanner crab populations.

Unexpected Population Increase with Fishing

 Pre-fishery populations of *C. opilio* were maintained in a stagnant phase by larger males which monopolized niche space and restricted resources available to pre-recruits. By removing large males, the fishery presumably relaxed competition and allowed greater survival and/or faster growth of pre-recruits, thereby contributing to increased stock productivity. (Waewood and Elner (1982) in Sainte-Marie et al. (1996))

Population Increase with Fishing

 "removal of adult males allowed prerecruitment survival rates of crayfish to the fishery to increase. As a result, expansion of the population took place despite increased trapping pressure." (Momot 1998)

Population Increase with Fishing

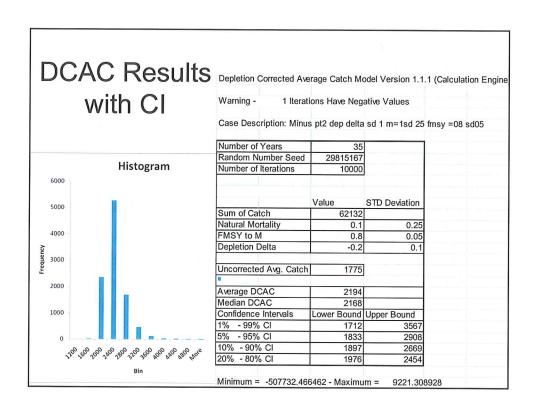
 "Culling experiments demonstrate sizeclass specific biomass increases with mortality." (Schroder, Persson, and de Roos 2008)

Population Increase with Fishing

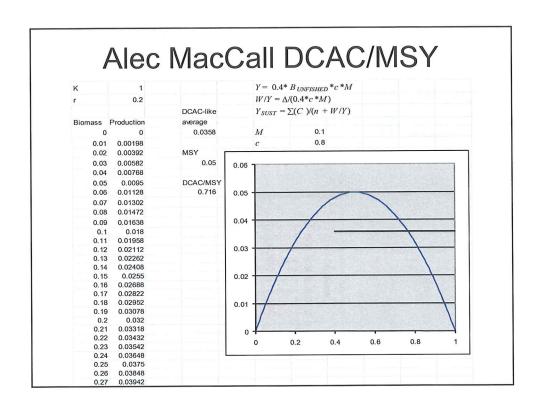
 "An intensive seven-year removal of adult, juvenile, and young-of-the-year smallmouth bass (*Micropterus dolomieu*) from a north temperate lake (Little Moose Lake, New York, USA) resulted in an increase in overall population abundance, primarily due to increased abundance of immature individuals." (Zipkin et al. 2008)

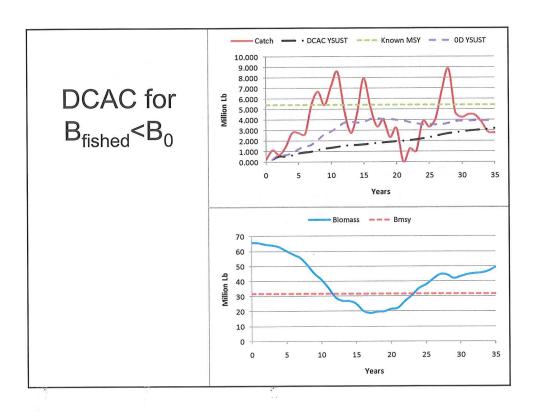
Additional Information and Analysis

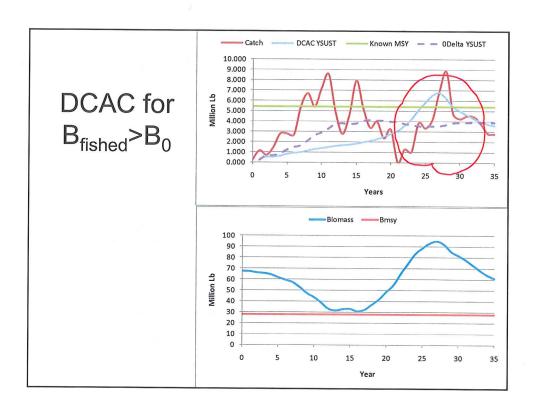
- Alternative Long-term Average Landings Calculations.
- Depletion-Corrected Average Catch (DCAC) Model
 - Zero depletion DELTA
 - -0.2 depletion DELTA
- Confidence intervals for DCAC results
- MSY to DCAC sustainable yield relationship
- Analysis of size distribution
- Yield per recruit analysis



		-0.2 Dep	letion Delta	0 Deple	tion Delta
	M=0.05			_	1
DCAC	Average DCAC	3441		1870	
	Median DCAC	2761		1781	
Confidence		LCI	UCI	LCI	UCI
	ACAMADA ANDONOMINE TO CAROLO	-4028	17833	1181	3553
Intervals	5% - 95% CI =	1862	7177	1340	2639
	10% - 90% CI =	2007	5154	1434	2356
	20% - 80% CI -	2210	3898	1545	2114
	M=0.10				_
	Average DCAC	2193		1797	
	Median DCAC	2168		1777	
	101 0001 01	LCI	UCI	LCI	UCI
	1% - 99% CI =		3567	1419	2367
	5% - 95% CI =		2907	1528	2123
	10% - 90% CI =		2668	1586	2025
	20% - 80% CI =	1975	2454	1652	1930
	M=0.15	0050			
	Average DCAC	2050		1786	
	Median DCAC	2019 LCI	LIOI	1777	
	1% - 99% CI =		UCI	4500	0404
	1% - 99% CI = 15% - 95% CI =	1732	2669	1520	2131
	10% - 90% CI =	1813 1854	2398	1602	1993
	20% - 80% CI =		2285 2176	1645 1691	1934
	20% - 00% CI =	1904	2176	1691	1875

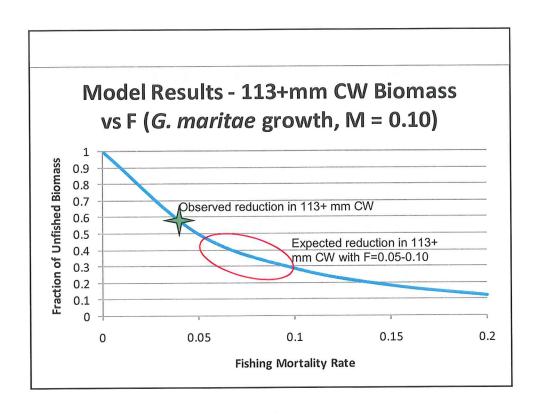


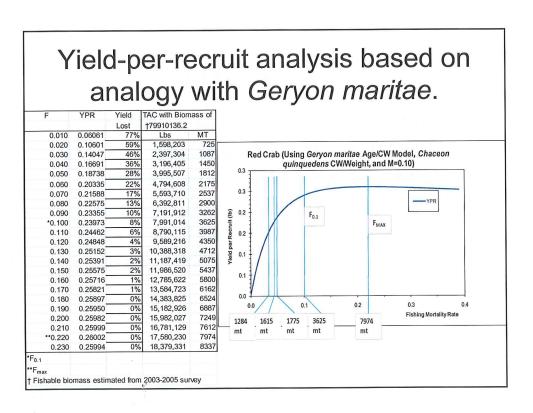




The Size Distribution Issue

 Analysis of expected size distribution of male crabs relative to exploitation rates based on age/CW model for *G. maritae*, the Namibian red crab; CW/weight model for *C. quinquedens*, with M=0.10.





Additional Information

SRR

- implications for expected biomass at maximum sustainable yield relative to unexploited biomass.
- Is there a consistent difference between Ricker and Beverton-Holt?
- $-0.5B_0$ vs $0.4B_0$

F_{MSY}/M Ratio

- DPSWG Walters and Martell (2004) suggest that FMSY is lower and approximately 0.8M for many species.
- Consideration of length at capture and length at sexual maturity as indicators of the appropriate F_{MSY}/M. (Hilborn 2010, MRAG 1996)

Garcia, Sparre and Csirke (1989)

Option 3e: MSY estimator based on Schaeffer Model.

$$MSY = \frac{(F_{MSY}B_c)^2}{2F_{MSY}B_c - Y_c}$$

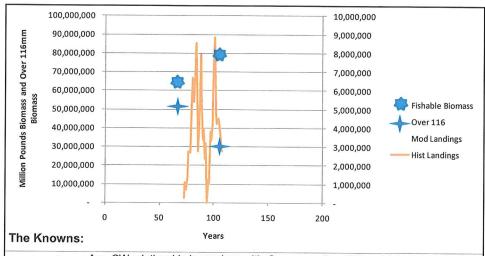
- MSY=(0.8*M*Bc)^2/2*M*0.8*Bc-Yc
- MSY=(0.8*0.1*36247)^2/2*0.1*0.8*36247-2040
- MSY=2237 mt
- Adjustment for Management Unit = 2386
- Option 3f: MSY estimator based on Fox Model

$$MSY = F_{MSY}B_c \exp\left(\frac{Y_c}{F_{MSY}B_c} - 1\right)$$

- MSY=.8*.1*36247exp(2040/(.8*.1*36247)-1)
- MSY=2156 mt
- Adjustment for Management Unit = 2251

Population Projection Models

- "Analysis of related stocks or species is a powerful tool for inferring the likely traits of stocks for which stockspecific data are unavailable or are not sufficient to produce reliable estimates." NS 2 Guidelines
- By analogy with age/CW for Geryon maritae
- CW/weight for Chaceon quinquedens
- Candidate SRRs to match known history
- Deterministic through 2010
- Stochastic projections
 - Variable M
 - Variable Recruitment



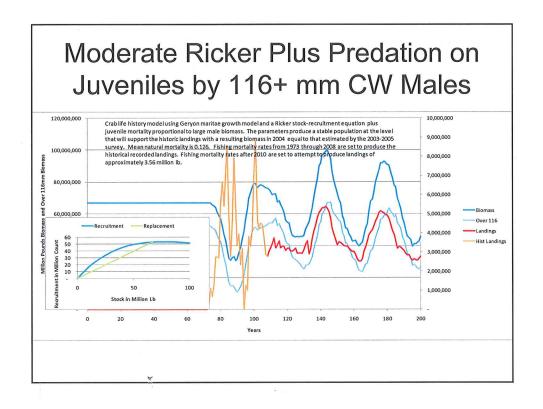
- Age-CW relationship by analogy with Geryon maritae; CW-weight relationship for Chaceon quinquedens;
- A natural mortality rate calculated to produce the size distribution that was observed in 1974, given the age-weight relationship.
- The historical landings, which may be under-reported to some extent in some years;
- The abundance by size estimated from the 2003-2005 survey.
- There is more uncertainty surrounding the population estimate from the 1974 survey. The size distribution should be reliable.

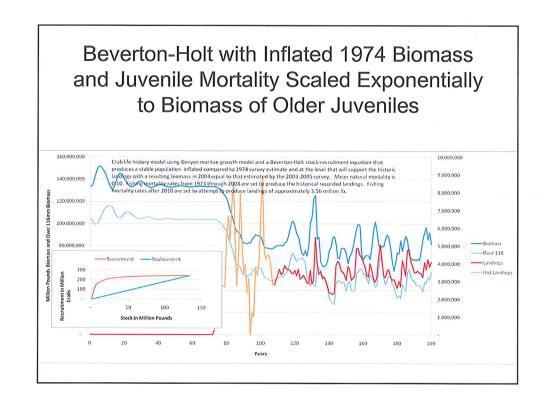
Deterministic Model

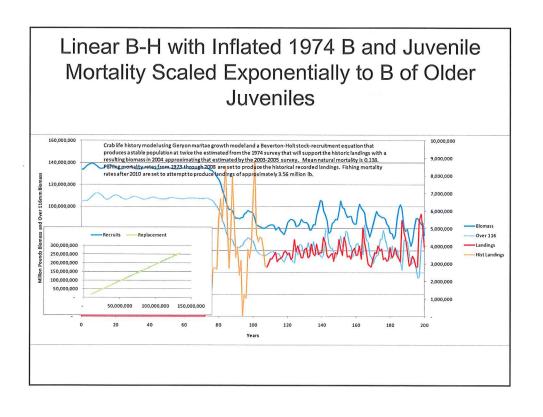
- Find Recruitment and M to produce equil initial biomass and size structure with SRR and/or juvenile mortality to produce 2003-2005 fishable biomass after removing landings
- Deterministic through 2010 to fit history
 - Solver to find Conditional MSY, F_{MSY} , B_{MSY}
 - 116+ mm CW males > 25% B $_{init}$

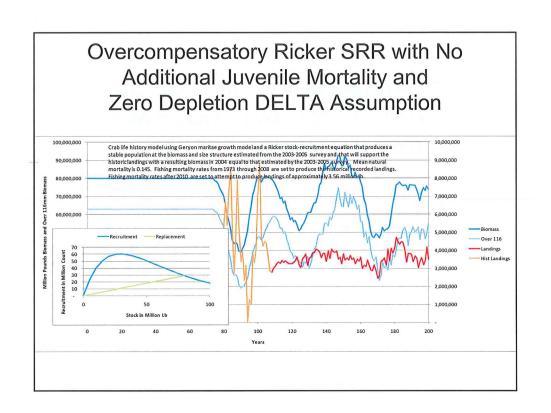
Monte Carlo Simulation

- Stochastic from 2011
 - M = NORMINV(RAND(), Deterministic M,0.05)
 - R = NORMINV(RAND(), Deterministic R, SD)
 - (SD ad hoc somewhat less than Deterministic R)
- Risk Measure One
 - % years B<0.5B_{MSY} after 300 runs of 89 yrs with TAC ≈ 615 mt
- Risk Measure Two
 - Mean and CI for 100 runs of 89 yrs
 - Conditioned on 116+ mm CW B>.25B_{init}

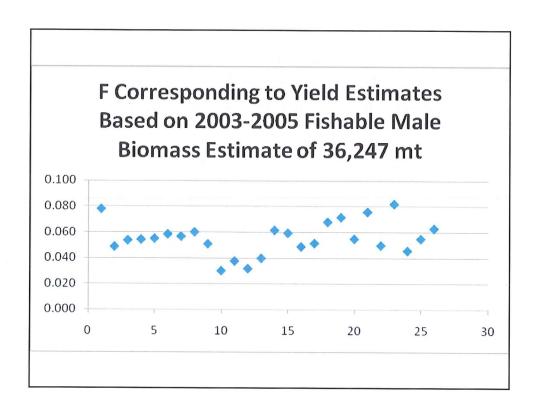






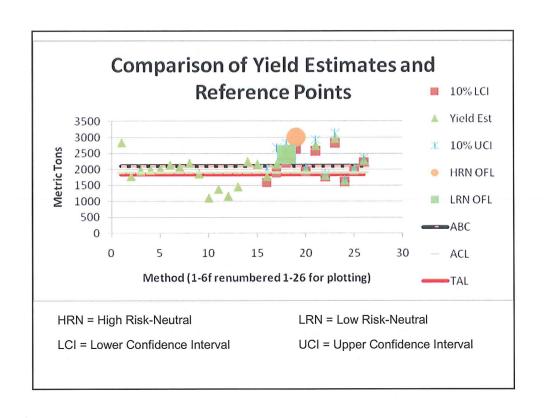


Plot #	Method	Y Est	20% LCI	10% LCI	
1	1	2830		14	· 1000 · 1
2	2a	1775			
3	2b	1954			A1((' \/' 1
4	2c	1975			Alternative Yield
5	2d	2002			Tutorriativo riora
6	2e	2126			
7	2f	2062			Estimates
8	2g	2185			
9	2h	1853			Daniel of Wald Catherine
10	/3a	1098			Range of Yield Estimates
11	3b	1372			3500
12	3c	1160			
13	3d	1450		1	3000
14	3e /	2237			و 2500
15	3f	2156			2000
16	4a	1777	1652	1586	10% It
17	4b	1872	1734	1668	× 1000
18	4c	2468	2294	2203	1000
19	4d	2600	2408	2317	500 ♦ 10% U
20	5	1996		1932	0
21	6a	2751	2615	2576	0 5 10 15 20 25 30
22	6b	1812	1774	1763	
23	6c	2974	2856	2822	Method (1-6f renumbered 1-26 for plotting)
24	6d	1662	1630	1621	
25	6e	1996	1966	1958	
26	6f	2286	2237	2224	



PDT Recomme	enda	tion	S	
Total Allowable Landings = 2002-2007 Avg. Landing MSY/OFL based on adjusted DCAC model results		% of Lower Risk Neutral	% of Higher Risk Neutral	% of Average of LRN and HRN
Total Allowable Landings of Male Red Crabs (TAL)	mt 1850	75%	MSY/OFL 61%	68%
Dead Discards (5% of 30% of Total Catch)	40	1370	01%	00%
ACL (10% buffer for Management Uncertainty)	1890			
ABC	2100	85%	70%	77%
*Lower Risk Neutral MSY/OFL	2469			
Avg of Lower Risk Neutral and Higher Risk Neutral MSY/OFL	2740			
*Higher Risk Neutral MSY/OFL	3011			
20% CI on Lower Risk Neutral MSY/OFL	2294			
20% Cl on Higher Risk Neutal MSY/OFL	2744			
* Risk neutral refers to the median DCAC model result divided	by 0.72 to	orovide an e	estimate of	MSY given
the model and the assumptions incorporated into the model ar sustainable yield estimates and MSY. The use of a zero deple	nd the expended	cted relatio A to produc	nship betwe	een DCAC r risk

* Risk neutral refers to the median DCAC model result divided by 0.72 to provide an estimate of MSY given the model and the assumptions incorporated into the model and the expected relationship between DCAC sustainable yield estimates and MSY. The use of a zero depletion DELTA to produce the "lower risk neutral" MSY/OFL estimate and the use of the 0.72 divisor to adjust from the DCAC results to MSY could be considered precautionary considering the expected range of 0.50 to 0.72. The use of an F_{MSY} to M ratio of 0.8 in the DCAC model may also be precautionary.



CI LCI 1% 1969 2100 5% 2122 2100 10% 2203 2100 20% 2294 2100 0.20 Depl DELTA DCAC/.72* Median 3011 2100 7 CI LCI 1% 2378 2100	n DCAC/.72* Recommended ABC edian 2469 2100 85
Median 2469 2100 8 CI LCI 2100 2100 5% 2122 2100 2100 2203 2100 20% 2294 2100 2100 200 2100 2100 200 2100 2100 200 2100	edian 2469 2100 85
Median 2469 2100 8 CI LCI 2100 2100 5% 2122 2100 2100 2203 2100 20% 2294 2100 2100 200 2100 2100 200 2100 2100 200 2100	edian 2469 2100 85
1% 1969 2100 5% 2122 2100 10% 2203 2100 20% 2294 2100 0.20 Depl DELTA DCAC/.72* Median 3011 2100 7 CI LCI 1% 2378 2100	CI ICI
5% 2122 2100 10% 2203 2100 20% 2294 2100 0.20 Depl DELTA DCAC/.72* Median 3011 2100 7 CI LCI 1% 2378 2100	
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20% 2294 2100	5% 2122 2100
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Median 3011 2100 7 CI LCI 1% 2378 2100	20% 2294 2100
CI LCI 2378 2100	ELTA DCAC/.72*
1% 2378 2100	edian 3011 2100 70
	CI LCI
F0/ 0F47 0400	1% 2378 2100
5% 2547 2100	5% 2547 2100
10% 2634 2100	10% 2634 2100
20% 2744 2100	20% 2744 2100

Potentially Precautionary Characteristics

- F_{MSY} to M ratio = 0.8
- Zero Depletion DELTA in DCAC
- M = 0.10
- Use of 0.72 for conversion of DCAC to MSY when range is 0.50-0.72.
- Use of sum of recorded landings in DCAC creates unknown downward bias
- Biomass estimates for SAW 43 don't include crabs deeper than 500F

Potentially Precautionary Characteristics

- B estimated for survey area not management unit (FMP incr by 13.6%)
- Strata A and D show less impact from fishing – Area south of Strata A likely similar
- Gulf of Maine population not included and no directed fishery
- No directed fishery on Canadian extension of population

Summary

- The PDT agrees with the recommendation of the DPSWG for "a catch limit that mimics both recent and long term mean annual landings..."
- The PDT agrees with the Review Panel preference for the DCAC model, but with an adjustment to reflect the expected difference between DCAC results and MSY.
- Recommendations combine both

1

Growth Model 1				tal	79-year	Molt Schedule	
Growth Model 2 7 yes 38,6139314 1.60678E-07 0.036680454 4 9 yes 48,0634259 2.5011E-08 0.072297846 5 10 yes 56,9291264 3.28972E-05 0.122184093 6 10 no 65,2470998 0.000368494 0.186465997 7 11 yes 73,0511849 0.003545124 0.28466043 8 11 no 80,3731301 0.02869381 0.355557776 9 12 yes 87,2472722 0.18052888 0.45866243 11 12 no 93,6879077 0.58815348 0.572310519 0.11 12 no 93,6879077 0.58815348 0.572310519 0.11 12 no 99,7349066 0.822159378 0.694725719 12 13 yes 105,408319 0.97270675 0.894725743 13 13 no 110,731226 0.99506974 0.69078964 0.11 13 no 115,7526281 0.998840023 1.101571736 0.9997149 0.99999149 0.999	Ngt grams	Wgt (lbs)	Selectivity	mmCW	Molt?	Age Instar	
Growth Model 4 9 yes	1.51			17.8072604			
Growth Model 4 9 yes	6.520	0.014374036	8.62595E-09	28.5422007	yes	2 7	
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35 16 no 171.692034 1 3.741616648 1 36 16 no 172.919903 1 3.75 1	1615.69	3.561987437	1	168.988414	yes	33 1	
36 16 no 172.919903 1 3.75 1	1657.389	3.653917284	1	170.383313	no	34 16	
	1697.169	3.741616648	1	171.692034	no	35 16	
	1735.07	3.75	1	172.919903	no	36 16	
37 16 no 174.071913 1 3.75 1	1771.15	3.75	1	174.071913	no	37 16	

Outstanding Issues

- Most appropriate years for average catch
- Most appropriate F_{MSY} to M ratio
- Confidence level in 1974 survey
- SRR and juvenile mortality projection
- CPUE and LPUE
- ABC Control Rule
- · Implications of possible stock cycling