IMPACT OF DERELICT TRAP REMOVAL ON BLUE CRAB LANDINGS

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BACKGROUND

The Chesapeake Bay Stock Assessment Committee (CBSAC) was asked by the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (GIT) to review the Bilkovic et al. (2016) report entitled "Ecological and Economic Effects of Derelict Fishing Gear in the Chesapeake Bay" to evaluate the reliability and implications of the report's findings for management of blue crab in Chesapeake Bay. The CBSAC members listed above have completed their evaluation of the findings in the Bilkovic et al. (2016) report. Where necessary, CBSAC reviewed the peer-reviewed scientific literature to assess the degree of support for individual elements of the 2016 report. Individual CBSAC members wrote independent reviews, which were then combined and edited to form this consensus evaluation. In addition, CBSAC reviewed the rebuttal by authors of the 2016 report to our initial evaluation. In this revised, final evaluation, CBSAC has integrated the elements of the original evaluation as well as responses to the rebuttal by authors of the 2016 report. Conclusions of the original evaluation by CBSAC have not been altered by the rebuttal.

CONCLUSIONS

CBSAC expresses extreme caution over the level of impact of derelict traps on the blue crab population in Chesapeake Bay, as claimed in the Bilkovic et al. (2016) report, because of numerous errors and incorrect assumptions in the report. CBSAC also questions the value of derelict trap removal (DTR) efforts on the long-term sustainability and productivity of the blue crab fishery.

There may be some limited benefits to the blue crab fishery associated with DTR where derelict traps are concentrated. This problem may also be lessened by implementation of methods that allow crabs to escape from derelict traps. These include the use of degradable elements in the trap, such as panels or inexpensive cord attached to trap openings. For instance, degradable cord is used in the Dungeness crab fishery (Redekopp et al., 2006) and blue crab fisheries in the Gulf of Mexico.

EVALUATION

Conversion Errors between Crab Weight and Abundance / Use of 2014 Landings when Calculating Impact of Derelict Traps

Bilkovic et al. (2016) (i) used an incorrect conversion factor between crab weight and abundance, (ii) used an incorrect equation to estimate the percentage of landings killed by derelict traps, and (iii) conflated harvest/catch with landings. These errors greatly exaggerated the percentage of potential crab landings killed by derelict traps.

For the conversion factor, the 2016 report stated that "2.1 crabs/lb" [*Section 3.1.2.2*] was used when converting landings in pounds to crab abundance. The correct conversion from pounds to crabs is approximately 3 crabs per lb (Miller et al., 2011; CBSAC, 2017), which has been used for nearly three decades by blue crab researchers, stock assessment scientists, and fishery managers (Knotts, 1989; Sharov et al., 2003; Smith and Chang, 2007; Miller et al., 2011). In their rebuttal, the 2016 report authors mentioned that they had been given the incorrect conversion factor by a staff member at VMRC. An examination of the published literature is expected in this situation, and would have led to a more accurate estimate.

Regardless of the rationale, this error has substantial impact on Bilkovic et al.'s (2016) conclusions. Bilkovic et al. (2016) claimed that "each year, derelict pots catch over 6 million crabs, and kill over 3.3 million—4.5% of the 73 million crabs harvested in 2014" [*Executive Summary*] and "results in an annual mortality of approximately 4.5% of the 2014 harvest (which was 35 million lbs @ 2.1 crabs/lb = 73 million crabs)" [*Section 3.1.2.2*]. Using the correct figure of 3 crabs per lb, the number of crabs landed in 2014 was 105 million crabs (35 million lbs x 3 crabs per lb), as opposed to the 73 million crabs estimated in the 2016 report. This error significantly overestimates mortality due to derelict traps.

We also note that the blue crab landings in 2014 of approximately 35 million lbs only includes commercial landings (CBSAC, 2017). If we include recreational landings and use the previously cited size conversions, the actual 2014 landings represent 111 million crabs, not 73 million crabs.

The authors presented the number of crabs killed in derelict traps in 2014 as an annual estimate representing multiple years, and not just as an estimate for 2014. For instance, the report used the 2014 landings value to justify the use of biodegradable panels in the future, not only for a year of low landings: "for example, biodegradable escape panels would likely reduce crab mortality in derelict pots from over 3.3 million **per year** [boldened for emphasis] (4.5% of the harvest) to under 440,000 (0.6%)" [*Executive Summary*]. Mean landings from 2009-2014 were 174.3 million crabs per year, in sharp contrast to the stated 73 million crabs landed in 2014, which were the lowest since

World War II and do not represent the average condition. Use of the 2014 landings as a point of comparison could mislead the public, policy makers, regulators, and fishery managers regarding the impact of derelict traps on the blue crab fishery.

Another error was that the 3.3 million crabs assumed to be caught in derelict traps represented harvest/catch from the derelict traps, not landings. In the fishery, harvest/catch is higher than landings due to discard of unwanted crabs (e.g., sponge crabs) and removal of crabs that die before being brought to port as landings.

This also seemed to assume that every crab caught by derelict gear could be legally landed otherwise. The authors clarified that the values presented in Table 3-1, "All blue crabs captured and killed," represented only crabs that were of legal size. It is unclear why sub-legal crabs were not included in the analysis, unless that information was not collected.

Estimated Effect of DTR on Blue Crab Landings

Bilkovic et al. (2016) stated that "pot removals increased the efficiency of active pots … for each [derelict] pot removed, harvests increased by 868 lbs" [*Executive Summary*]. An active trap adds about 156 lbs per year to landings (Maryland DNR data for 2009-2017), which means that the suggested increase in landings due to removal of a derelict trap is 556% higher than the actual landings from an active trap. In addition, the 2016 report lists a value of 23 crabs killed per trap annually [*Table 3.1*], which equates to an annual loss per trap of about 8 lbs (23 crabs killed per trap x 3 crabs per lb). It is unclear from the report or supporting documents how the removal of derelict traps can add more crabs to landings than the traps would catch if left active in the water. Similar studies (Gilardi et al., 2010; Antonelis et al., 2011) cited only the estimated catch from derelict gear (e.g., 8 lbs) as a benefit to the fishery after removal of derelict gear.

Bilkovic et al. (2016) estimated that DTR increased blue crab landings by "a Bay-wide total of over 38 million lbs (23.8%, valued at $33.5 million) over the 6 year period [2009-2014]" [*Executive Summary*]. The actual landings estimated by CBSAC for 2009-2014 were 334 million lbs (CBSAC, 2017). The increase in landings due to DTR would then be 38/(334-38) = 12.8% not 23.8%. Fundamental questions remain about the methodology used to estimate 38 million lbs of additional landings generated by DTR, so any benefit would be much lower than even 12.8%.

Another problem involves significant overestimation of the number of traps fished in Virginia, such that the number of derelict traps is also substantially overestimated. Not all licensees actively fish (about 1/3 are inactive) and the maximum number of traps allowed under each license does not always correspond to the number of traps that waterman actively fish.

Reliability of Spatial Statistical Analyses

Bilkovic et al. (2016) combined the results of side-scan sonar (Maryland) and actual trap collections (Virginia) to estimate the total number of derelict crab traps. These numbers were expanded statistically using geographically weighted regression (GWR) to predict the total number of crab traps baywide. GWR performs well when used for statistical inference, but it performs poorly when used for statistical prediction (Harris et al., 2010). The original author of GWR recommends ordinary kriging when prediction is the objective. In addition, as employed here, GWR utilizes Euclidean or straight-line distances as part of its estimation process. Application of Euclidean distance in estimating abundance in estuarine surveys has been criticized previously (Jensen et al., 2006). There are more recent versions of GWR that employ the preferred "through the water" distance measure (Lu et al., 2014), which improves performance. Indeed, inspection of Figure 2-8 in Bilkovic et al. (2016) clearly shows that the GWR model performed poorly ($R^2 \cong 0.1$) in highly invaginated regions of the prediction surface, further supporting concerns over the application of simple GWR. Hence, the estimate of 145,233 derelict traps is associated with unknown bias (= inaccuracy) and precision. The 2016 report authors did not provide a detailed written response to these criticisms.

Overestimation of the Number of Derelict Traps

Our initial criticism regarding the estimate of 145,233 derelict pots cited the published results from Bilkovic et al. (2014) stating that only ~35% of derelict pots were capable of capturing and retaining crabs. If the total number of derelict traps included all traps, regardless of condition, it would have over-estimated the number of crabs caught by a factor of 2.8. The authors' response was that 145,233 represented just the number of functional traps despite reporting this figure as "the total number of derelict pots in Chesapeake Bay" and not explaining how functional vs. non-functional traps were parsed in the GWR model.

Overestimation of the Catch Rate by Derelict Traps

Bilkovic et al. (2016) multiply the number of traps by assumed catch and mortality rates to estimate 23 crabs killed yearly per derelict trap. Estimates of trap bycatch rates are notoriously difficult to derive and methodological differences account for much of the variability among studies as reported by Sturdivant and Clark (2011) and in the 2016 report [*Table B-1*]. For example, Havens et al. (2008) studied experimental crab traps that had been intentionally abandoned and estimated 50.6 crabs are trapped annually. Another study conducted more recently by the report's authors estimated that 65 crabs are trapped each year. Other studies found 21, 40, 40.8, and 48 crabs per year [*Table B-1*]. What was unclear is why the authors used the study with the highest annual catch rate of 65 crabs per trap, rather than lower estimates.

Another problem with the use of the recent experiment is the assumption that catch rates from experiments conducted separately several times per year in mesocosms or in the field represent the cumulative effects of actual derelict traps in the field. This assumption reflects an additive catch process, meaning that one can simply add up the number of crabs entrapped and killed over all the discrete samples within a year to estimate annual rates. In reality, catch and mortality rates of derelict traps are not constant over time, and change due to alterations in the conditions of and in the traps over time. There are theoretical (Fogarty and Addison, 1997), behavioral (Sturdivant and Clark, 2011), and empirical studies (Casey and Wesche, 1977; Whitaker, 1979; Arcement and Guillory, 1993; Guillory, 1993, 2001; Bullimore et al., 2001; Antonelis et al., 2011) demonstrating that mortality from crab traps is non-additive. In a review of blue crab mortality due to ghost traps, Guillory (2001) stated "Entry of blue crabs declines as traps deteriorated" and "Highest mortalities in ghost traps occur immediately after a trap converts from actively fishing to a ghost fishing mode" [p. 35]. Several studies on the blue crab (Casey and Wesche, 1977; Whitaker, 1979; Arcement and Guillory, 1993; Guillory, 1993; Guillory, 2001) confirm that catch rates are not additive.

Dr. Havens commented at the Fisheries GIT conference call that CBSAC was wrong about the findings of Bullimore et al. (2001), and that they demonstrated additivity. This is clearly mistaken. Bullimore et al. (2001) demonstrated that CPUE [number of newly caught spider or brown crabs per trap per day] declined as an inverse (negative exponential) function of time, rather than remaining constant (i.e., linear, additive). For instance, CPUE of spider crabs declined from 1.25 on day 1, to 0.08 on day 4, and 0.06 on day 27, after which it leveled off (Table 2 in Bullimore et al., 2001).

Based on all of the published studies on non-additive catch rates over time (Casey and Wesche, 1977; Whitaker, 1979; Arcement and Guillory, 1993; Guillory, 1993, 2001; Bullimore et al., 2001; Antonelis et al., 2011), we conclude that the simple assumption of additive catch rates in derelict crab traps leads to an unknown, but likely substantial overestimate of the ultimate catch, and thus the impact of derelict traps on the crab population and fishery.

Preliminary Findings from Ongoing CBSAC Analysis on the Effects of Fishery Management Actions and Derelict Trap Removal on Blue Crab Abundance and Landings

CBSAC has been analyzing abundance and landings data in relation to fishery management actions in 2008-2009 and the derelict trap removal program. These analyses indicate that fishery management actions were responsible for most of the increased landings from 2009-2014 due to concomitant increases in blue crab abundance and fishing effort. There was little evidence of an effect of the derelict trap removal program on either blue crab abundance or landings. These preliminary findings are consistent with CBSAC's evaluation of the 2016 report, and will be presented to the Fisheries GIT at a future meeting.

Bycatch of Atlantic Croaker

VMRC pointed out concerns about finfish bycatch estimates, particularly for Atlantic croaker. The 2016 report estimated that 3.6 million croaker are caught in Chesapeake Bay each year in derelict traps, with the vast majority caught in Virginia. In recent years the total croaker catch from all gears was around 3 million lbs. With an average weight of 0.5 lbs, this represents 6 million fish. It is legal to harvest croaker from crab traps, and that practice has always occurred. The derelict trap estimate dwarfs the reported catch of Atlantic croaker from commercial crab pots: 7,829 lbs in 2014, 1,991 lbs in 2015, and 2,386 lbs in 2016. Thus, CBSAC believes that the bycatch of Atlantic croaker has been greatly overestimated in the 2016 report.

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