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Evaluation of Fisheries Resource Data Collection, Analysis and Availability: An Example Protocol Using the Blue Crab

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Abstract

The overall goal of this study was to provide an example protocol for evaluating the efficacy of fisheries resource data collection by combining the strengths of historical and current databases for the blue crab in North Carolina, with recent advances in stock assessment techniques, modern ecological theory, and principles of sampling and experimental design.

The specific objectives were to:

1. Evaluate the reliability of historical and current North Carolina Division of Marine Fisheries (NCDMF) data collection techniques

2. Prioritize historical data sets in terms of analysis, interpretation and potential products

3. Identify management problems and major information gaps requisite to a blue crab fisheries management plan

4. Link specific data sets with appropriate stock recruitment and assessment models

5. Design a rigorous and efficient stock assessment program

6. Suggest ways to make data available to potential users

Evaluation of Fisheries Resource Data Collection, Analysis and Availability: An Example Protocol Using the Blue Crab

Final Report to the
North Carolina Marine Fisheries Moratorium Steering Committee

February 8, 1996

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Executive Summary

The overall goal of this study was to provide an example protocol for evaluating the efficacy of fisheries resource data collection by combining the strengths of historical and current databases for the blue crab in North Carolina, with recent advances in stock assessment techniques, modern ecological theory, and principles of sampling and experimental design.
The specific objectives were to: (i) evaluate the reliability of long-term and current NCDMF data collection techniques; (ii) prioritize historical data sets in terms of analysis, interpretation and potential products; (iii) identify management problems and major information gaps requisite to a blue crab fisheries management plan; (iv) link specific data sets with appropriate stock-assessment models; (v) design a rigorous and efficient stock assessment program; and (vi) suggest ways to make data available to potential users.

A total of six blue crab databases were identified as relevant to the study objectives. Problems associated with these data sets were identified and recommendations for future program narratives were made. Data sets associated with Program's 120 (juvenile survey) and 195 (adult survey) were rated as a top priority in terms of data reduction and analysis. These data have the highest potential to provide an annual index of (i) spawning biomass; (ii) juvenile CPUE; and (iii) adult CPUE, which can be used in stock-recruit, recruit-stock, and surplus production models. Program's 120 and 195 represent relatively reliable 18 and 9 year databases, respectively. Primary management issues for the blue crab include how to effectively deal with (i) increasing fishing effort; (ii) stock assessment deficiencies; and (iii) wasteful harvesting practices. Proper management of the blue crab in NC requires sound-wide estimates of (i) commercial fishing effort; (ii) recreational catch and effort; (iii) mortality rates; (iv) stock-recruit and recruit-stock relationships; and (v) the effects of environmental variables and anthropogenic impacts on population dynamics. This information could be provided through (i) daily trip-tickets that require information on commercial effort and location caught; (ii) a blue crab recreational license that requires landings and effort data; and (iii) measures of DO, pH and certain nutrients at all DMF sampling stations. Juvenile crab bycatch in trawl fisheries could be significantly reduced through use of (i) "skimmer" versus "otter" trawls; (ii) a 4.5 in. stretched mesh tailbag; (iii) area and season closures to trawling in preferred molting habitats; and (iv) a 0% tolerance level for sublegal crabs. Statistical comparisons of CPUE between habitat types (e.g., seagrass, coarse woody debris, etc.) and body size are invalid without first adjusting these data for potential habitat-specific biases in gear selectivity (catchability). It is critical that crab size- and habitat-specific gear efficiency studies be conducted as soon as possible. Recommendations are provided regarding how to assess the relationship between (i) crab abundance and harvest; (ii) crab distribution and abundance patterns, and environmental and habitat variables; (iii) stock-recruit and recruit-stock relationships; and, how to estimate (iv) annual spawning stock biomass; and (v) crab mortality rates. Recommendations are also provided for designing a sound-wide blue crab stock assessment program. Finally, we recommend that a "Cooperative Fisheries Research Institute" be established to (i) serve as a central clearinghouse for data; and (ii) support collaborative efforts between the NCDMF and academia through the use of graduate and undergraduate students. A Cooperative Fisheries Research Institute would set an unprecedented example of how state and university researchers could effectively address issues critical to NC, while training students for the future. Many of the concerns

and recommendations made in this report are applicable to numerous economically important species in NC. This study should serve as a guide for future efforts aimed at evaluating fisheries resource data collection, analysis and availability.

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Introduction

Traditional fisheries stock assessment tools have developed around the availability of two types of data: (i) fisheries-dependent data, such as catch, effort, catch-at-age and length distributions; and (ii) fisheries-independent data, which typically uses some form of catch-per-unit-effort (cpue) to derive an annual recruitment index for forecasting year-class strength (Rothschild 1986, Hilborn 1992). There are many potential strengths and weaknesses to both types of data (summarized in Rothschild 1986, Peterson 1990, 1993, Hilborn 1992), which must be recognized and incorporated into the design of any rigorous and efficient fisheries stock assessment program. The strengths of historical fisheries surveys include: (i) the use of spawning stock biomass or juvenile recruitment indices to forecast fishery year class strength (e.g., Phillips 1986, Lipcius and Van Engle 1990); (ii) the ability to test hypotheses regarding the outcome of management regulations (e.g., Peterson 1990, 1993); and (iii) the ability to identify key physical and biotic processes, and anthropogenic impacts influencing recruitment success on a landscape scale (e.g., Peterson 1990, 1993). Weaknesses which continue to plague Federal and State fisheries agencies (summarized in Caddy 1989, Hilborn and Walters 1992, Gunderson 1993) include: (i) biases associated with sampling gear, habitats, life history stages, etc.; (ii) lack of replication; (iii) inadequate spatial and temporal coverage; (iv) no linkage between management regulations and population responses; (v) lack of hypothesis testing; (vi) inappropriate statistical analyses; and (vii) inaccessibility of data and results to appropriate user groups. Given budgetary constraints facing most State and Federal fisheries agencies, combined with an urgency for protecting diminishing fisheries stocks, it is critical that we begin to use the collective expertise of State, Federal and academic scientists to inventory and evaluate current fisheries data collection, analysis and communication techniques.

Objectives

The overall goal of this study was to provide an example protocol for evaluating the efficacy of fisheries resource data collection by combining the strengths of historical and current databases for the blue crab in North Carolina, with recent advances in stock assessment techniques, modern ecological theory, and principles of sampling and experimental design.

The specific objectives were to:

1. Evaluate the reliability of historical and current North Carolina Division of Marine Fisheries (NCDMF) data collection techniques;

2. Prioritize historical data sets in terms of analysis, interpretation and potential products;

3. Identify management problems and major information gaps requisite to a blue crab fisheries management plan;

4. Link specific data sets with appropriate stock-recruitment and -assessment models;

5. Design a rigorous and efficient stock assessment program; and

6. Suggest ways to make data available to potential users.

Results

Objectives 1-2. Historical Databases and Priorities

A total of six NCDMF blue crab databases (Table 1) were identified as relevant to the study objectives. We evaluated the program narratives for these six programs. Specific questions, concerns, and suggestions for each sampling program were summarized according to the examples shown in the Appendices. General recommendations for future narratives are shown in Table 2. Small-scale, short-term sampling programs (e.g., Program's 471 & 532) were generally effective in addressing immediate management needs. Data sets associated with Program's 120 and 195 were rated as a top priority in terms of data reduction and analysis. These data have the highest potential to provide an annual index of (i) spawning biomass; (ii) juvenile CPUE; and (iii) adult CPUE, which can be used in stock-recruit, recruit-stock, and surplus production models. Moreover, these data sets contain valuable information concerning habitat-specific abundance patterns, environmental correlates with distribution and abundance patterns, and potential anthropogenic impacts. Problems associated with these data sets are summarized in Table 3.

Data Sets

A. Program 120

Program 120 was initiated in 1970 as a monthly, shallow water (< 2m) juvenile survey in primary nursery habitats. Data generated through program 120 prior to 1978 is problematic due to changes in gear, towing speed, and no data on crab sex or whether stations were subject to commercial trawling (Table 3). After 1978, the gear was standardized to a 4 m otter-trawl with 0.64 cm mesh, and towing time and distance of 1 min. and 75 yds. Also, after 1978, blue crabs were separated by sex and maturity, and stations subject to commercial trawling were identified. Initial selection of station locations was haphazard. After 1978, sampling stations were stratified according to six water bodies: (i) N. Pamlico Sound (Stumpy Pt. Bay to Abel's Bay); (ii) Pamlico & Pungo Rivers; (iii) western Pamlico Sound and Neuse River (Pamlico Pt. to Cedar Pt.); (iv) Outer Banks (Roanoke Isl. to Ocracoke Inlet); (v) Core and Bogue Sounds (Cedar Island to Bouge Inlet); and (iv) Southern area (Bogue Inlet to S. Carolina line). The number of stations has ranged from 48-216 since 1978. Presently, there are 105 core stations in this program. In 1989, the sampling frequency was reduced to twice per year (May & June). Program 120 represents a relatively reliable 18 year data base (1978-95).

B. Program 195

Program 195 was initiated in 1987 as a deep water (> 2m) adult survey in the Pamlico R., Neuse R., Pungo R. and Pamlico Sound. The gear used is a 9.1 m "Mongoose" trawl with a 1.9 cm cod-end. This is a stratified random sampling scheme based on area, with a total of 52 stations sampled in March, June, September and December each year. In 1990, the sampling frequency was reduced to twice per year (June & Sept.). Presently, there are 50 core stations. Program 195 represents a relatively reliable 9 year database (1987-95).

C. Fisheries Landings

The NCDMF can print annual summaries of monthly hard blue crab landings for 27 water bodies in North Carolina (e.g., Albemarle Sound, Alligator R., Pamlico R., Pungo R., Bay R., Neuse R., Pamlico Sound and Outer Banks (including bays within Pamlico and Hyde Cos.). The previous examples highlight the more important water bodies in NC in terms of blue crab landings. Effort data is unavailable.

Objective 3. Management Problems and Key Information Gaps

Primary management problems for the blue crab include: (i) increasing fishing effort; (ii) stock assessment deficiencies; and (iii) wasteful harvesting practices.

A. Increasing Fishing Effort and Stock Assessment Deficiencies

The total amount of gear used and the number of participants in the crab fishery has increased over time. There is a lack of information concerning the impact of commercial and recreational crabbing on blue crab abundance in the Croatan, Albemarle and Pamlico estuarine system (CAPES). Our understanding of the population dynamics of the blue crab would be improved by obtaining additional information on (i) commercial fishing effort; (ii) recreational catch and effort; (iii) mortality rates; (iv) stock-recruit and recruit-stock relationships; and (v) the effects of environmental variables and anthropogenic stressors on population dynamics. Proper management of the blue crab in North Carolina requires annual sound-wide estimates of fishing mortality, stock size, and total exploitable biomass. These estimates should be based on data from (i) NC DMF trawl surveys; (ii) various components of the commercial and recreational fishery; and (iii) estimates of natural mortality, growth and weight-at-age from previously published studies. Daily trip-tickets must require information on commercial effort as well as location caught. A blue crab recreational fishing license and trip-ticket would quantify landings and effort. Finally, to begin to understand the effects of water quality on blue crab population dynamics, it is essential that NCDMF fishery-independent sampling efforts include station measures of DO, pH, and a water sample for subsequent laboratory nutrient analyses.

One tool to prevent overfishing is to establish annual targets such as measures of optimum levels of abundance, fishing mortality, spawning stock biomass, and yield-per-recruit. Such targets can be used as an annual index to determine if fishing pressure is increasing, and should allow for early detection when harvest rates are too high to be sustained. In the event that the blue crab resource does become overfished, targets can be used to alter harvest rates so that restoration can occur. It is critical that any future management plan for the blue crab in North Carolina establish specific targets to prevent overfishing.

B. Wasteful Harvesting Practices

Bycatch of small crabs in the shrimp and crab trawl fisheries does not maximize yield from the harvest, and increases mortality of sublegal crabs. Wasteful harvesting practices include: (i) small mesh (e.g., 3 in.) tailbag on crab trawls; (ii) ghost crab pots; (iii) bycatch from shrimp trawling; (iv) trawling in preferred molting habitats; (v) mortality in shedding operations; and (vi) a 15% tolerance level for sublegal blue crabs. Previous studies suggest that crab bycatch in trawl fisheries could be significantly reduced through the use of (i) "skimmer" versus "otter" trawls for white shrimp (*Penaeus setiferus*) (Coale et al. 1994); (ii) a 4.5 in. stretched mesh tailbag in otter trawls (McKenna and Clark

1993); (iii) area and season closures to trawling in preferred molting habitats; and (iv) a 0% tolerance level for sublegal blue crabs.

Objectives 4-5. Stock Assessment

A. Habitat-Specific Biases in Otter-Trawls

The overall efficiency of sampling gear such as trawls can vary dramatically as a function of animal body size and bottom type. The catchability of blue crabs probably varies according to carapace width and habitat type, which would invalidate comparisons of abundance across habitats. For example, one could not compare CPUE between stations located in seagrass areas with stations containing coarse woody debris or unstructured bottom, without first adjusting these data for habitat-specific differences in catchability. The solution to this problem is to conduct habitat- and crab size-specific gear efficiency surveys in seagrass, coarse woody debris, and unstructured, soft-sediment habitats. Protocol for estimating gear efficiency may be found in Gunderson (1993, pgs. 42-52) and references therein.

B. Blue Crab Distribution and Abundance Patterns

After adjustment of habitat- and crab size-specific catchability of gear from Program's 120 and 195, long-term data sets should be examined for spatial and temporal patterns in crab abundance. Initial data analyses should assess the relationship between crab abundance and commercial harvest, and between crab distribution and abundance patterns and environmental and habitat variables. To assess the relationship between crab abundance and harvest, it is critical that fishery-independent data be initially stratified according to the water bodies for which commercial landings are available (i.e., Pamlico R., Pungo R., Bay R., Neuse R., Pamlico Sound). These water bodies should be further stratified according to water depth: shallow (< 2 m) and deep (> 2 m) (Ross and Epperly 1985, R. Lipcius, Virginia Institute of Marine Science, pers. comm.), and, where applicable, upriver (salinity < 15 ppt) versus downriver (salinity > 15 ppt). Moreover, given that station assignment in Program 120 was not random, a subset of stations should be randomly selected from all stations within a particular strata for statistical analyses. Initial analysis should involve examination of three size groups of crabs, by sex. The size categories (carapace width, CW) are as follows: group 0: CW < 50 mm; group I: 50 < CW < 120 mm; and group II: CW > 120 mm. Groups 0, I, and II correspond approximately to 0, 1, and 2+ year old crabs, respectively. Crabs in group 0 would appear in the fishery after one or two growing seasons. The data should be further partitioned on a monthly basis by depth and salinity within each location (i.e., water body). The mean number of crabs per tow within a particular size class and sex can then serve as response variables in various multi-way ANOVA models with location (water body), depth, salinity, month and year as factors. This initial exercise will put the data in a manageable form, identify trends, and highlight data sets for meeting the specific objectives below (e.g., index of spawning biomass). All ANOVA and regression procedures should follow guidelines set forth in Underwood (1981) and Draper and Smith (1981).

Hard blue crabs 127 mm and larger can be legally harvested in North Carolina. Mean monthly trawl catches per tow from program's 120 and 195 should be correlated with their respective month's landings to determine if catch-per-tow of legal-size crabs is associated with commercial landings.

Knowledge of this relationship is critical in establishing "quick response" management targets such as optimum levels of abundance, fishing mortality and yield-per-recruit.

To determine the relationship between crab distribution and abundance patterns, and environmental and habitat variables, a second stratification scheme should be employed based on habitat characteristics and physicochemical parameters. This would involve station stratification based on habitat characteristics and physicochemical parameters. A good example of this stratification scheme may be found in Ross and Epperly (1985). They used classification analysis of eleven physicochemical variables measured during 1981-82 to identify *a priori* station groupings for sites located along the western and southwestern shores of Pamlico Sound (Ross and Epperly 1985). This procedure uses Morisita's index of overlap (Morisita 1959), and should be applied to a long time series (dictated by length of the data set), and include stations along the Outer Banks, Croatan and Albemarle Sounds. Once station locations are grouped according to environmental characteristics, trends in abundance, size frequency, and CPUE should be analyzed in a manner similar to that described above. This "biologically-based" approach is important in defining sound-wide trends in abundance and population dynamics.

C. Stock Assessment Models and Parameters

After initial examination of blue crab distribution and abundance patterns, the following relationships and parameters should be identified and estimated, respectively: (i) annual index of spawning biomass; (ii) recruit-stock and stock-recruit relationships; (iii) crab mortality rates; and (iv) the relationship between crab abundance and commercial harvest.

(i) Annual index of spawning biomass

Indices of spawning stock biomass could be generated by examining the abundance (catch per tow) of mature females captured in Program's 120 and 195 during May-September in the different water bodies. Because it targets adults, Program 195 will probably be the best data set for this objective. The first goal is to identify which combination of location (e.g., water body & depth), salinity, and month(s) provides the highest abundance of mature females. This goal will be accomplished by initially collapsing the data across years and analyzing catch-per-tow of mature females with a four-way ANOVA with water body, depth, salinity, and month as factors. Stations with the highest abundance will serve as an annual index of spawning biomass (1978-95), and these data could be correlated with commercial landings from a winter trawl fishery in eastern Pamlico Sound, that captures primarily mature females. This exercise will identify if certain fishery-dependent data sets can be used to provide a measure of spawning stock biomass. To determine the relationship between fishing and spawning stock biomass, regression analysis could be employed with spawning stock biomass in year t as the dependent variable, and commercial landings in year t-1 as the independent variable.

(ii) Potential recruit-stock and stock-recruit relationships

This is one of the most important objectives in terms of being able to forecast year class strength in advance (e.g., the relationship between juveniles caught in the late summer-early fall, and harvest the following summer), as well as for identifying the impact of fishing on the spawning stock (e.g., relationship between commercial harvest and spawning stock biomass lagged by 1-2 years). A general connection between the abundance of recruit crabs from fishery-independent surveys and future harvest has been made for both the Chesapeake and Delaware Bays (Speir et al. 1995). Moreover, trawl CPUE of mature crabs (> 4.7 inches or 12 cm) correlated positively with commercial landings and effort (Lipcius and Van Engle 1990, Speir et al. 1995). In Chesapeake Bay, Lipcius and VanEngle (1990) also found a significant relationship (i.e., Ricker S-R function) between stock abundance in year t_{-2} and recruit abundance in year t. These relationships are unknown in North Carolina.

Various basic functions relating recruits-recruits, recruitment-spawning stock, and spawning stock-recruitment should be generated using data from the fishery and Program's 120 and 195. For example, mean monthly catches per tow of blue crab recruits (group 0) for May, June, and July of year 1, could be correlated with either monthly catch per tow of adults, or commercial landings 14 months later. Recruits from August and September could be correlated with similar adult data 21 months later. These lags conform to Van Engle's (1958) observations of blue crab growth. This analysis should initially proceed by employing simple linear regression models and, if necessary, various transformations to achieve linearity and random, normally distributed residuals. When these models are inadequate, a series of non-linear stock-recruitment functions (e.g., Ricker, Beverton-Holt, Shepherd) should be applied to the data. The general application of these models, and tests for the best-fit could follow procedures set forth in Eggleston (1990), Lipcius and VanEngle (1990) and Hilborn and Walters (1992).

(iii) Crab mortality rates

Annual mortality of blue crabs should be estimated from average CW of crabs from trawl surveys and follow procedures outlined in Gulland (1983) and Casey et. al (1991). Briefly, instantaneous mortality rates (z) can be derived from information on growth rates, combined with average CW at recruitment into the commercial catch, and average CW of crabs in trawl catches:

$$z = K(L\ - l) / l - l';$$

l' = the minimum legal CW of hard crabs in the fishery;
l = the average CW of crabs in the trawl samples computed from l' upwards;
L = mean asymptotic CW (ultimate) for a crab if it continued to live and grow indefinitely (227 mm from Van Heukelem 1991);
K = rate at which asymptotic growth was approached.

Month, area and sex data can be pooled to estimate l. Annual mortality can then be calculated as

$$A = 1 - e^{-z}.$$

K can be estimated from a modified von Bertalanffy growth equation. The lifespan of molt stages 0 to n is written as a composite relationship

$$K = (1 / t_n - t_o) \times \log_e (L\ - L_o / L\ - L_n);$$

t_n = age at last molt (3 years);
t_0 = age at first molt (0 years);
L_0 = size at first molt (1 mm);
L_n = size at last molt.

Crabs seldom live past three years (Van Heukelem 1991), so this can be used as the age at last molt. Size at first molt is equal to the size of zoea at hatch, and size at last molt is the average length of two year old crabs in the winter trawl fishery.

Trawl survey size-frequency distributions can be used to compare relative mortality rates of different year classes, to estimate relative amounts of natural and fishing mortality, and to examine differences in relative mortality between sexes. In Chesapeake Bay, this approach has yielded fishing mortality estimates of 82-84% for legal-size male crabs, and 35-64% in legal-size females (Casey et al. 1991). Natural mortality rates ranged from 0.1 to 0.5 (Casey et al. 1991). Natural versus fishing mortality rates are unknown for North Carolina.

(iv) Sound-wide blue crab stock assessment program

Presently, the NCDMF trawl survey program's 120 and 195 are conducted only twice per year, with spatial coverage of program 120 biased towards southwestern Pamlico Sound, and a lack of upriver and downriver station stratification in program 195. Moreover, no sampling programs are operative in Albemarle Sound, despite an intense blue crab fishery in this area. Determining the sound-wide abundance of the blue crab in the CAPES requires a stratified random sampling program conducted at least bimonthly. The simplest and most realistic solution to this problem (in terms of station sample size) would be to stratify the CAPES according to location, depth and salinity (as described above), and allocate station sample sizes based on area of a particular strata within a location (e.g., Gunderson 1993). To determine an adequate number of stations within a strata, one can examine historical data from program 120 to identify the relationship between variance in both abundance and CPUE, and the number of stations. We anticipate that a moderate number of stations from program's 120 and 195 will serve as "core" stations for this effort. This will probably result in a significant reduction of effort (i.e., number of stations) for Program 120, which would offset increases in spatial coverage for program's 120 and 195, as well as sample size in Program 195. For areas that lack reliable variance estimates, such as Albemarle Sound, pilot surveys should be conducted as soon as possible to generate variance estimates that will be used to calculate station sample sizes.

Objective 6. Data Availability

A common problem with State and Federal resource agencies that generate large, long-term data sets is inaccessibility of data and results to appropriate user groups. Most agencies are understaffed, and can barely maintain field sampling programs and publish "short-fuse" progress reports, rather than providing comprehensive data analyses and interpretation. The ultimate goal is to facilitate efficient communication of fisheries research needs and information generated by the NC DMF and academia to each other, and to enhance their collective ability to provide timely answers to key questions facing the State. One solution to this problem is to establish a "Cooperative Fisheries Research Institute". The Institute would serve two primary functions: (i) provide a central clearinghouse for data; and (ii) support collaborative efforts between the NC DMF and academia through the use of graduate and undergraduate students. Initially, infrastructure and funding could be similar to that of the Cooperative Institute of Fisheries Oceanography, except that the research would emphasize retrospective data analysis, and funding would come primarily from the state. A Fisheries Research Institute board, comprised of members from the NCDMF or Marine Fisheries Commission and academia, would provide an annual list of research/data analysis priorities. The academic community would respond to the list of priorities by contacting the appropriate DMF researcher, identifying a prospective student(s), and submitting a proposal for peer and internal review. Approximately 80% of the total financial support could be devoted to 12 month graduate research assistantships that would focus on longer term problems, and the remaining 20% could be used to support graduate and undergraduate summer internships that respond to specific, short-term analysis and research needs (impact of fish kills on local fish abundance).

The advantages of increased collaboration between university and state researchers working on common problems include but are not limited to the following.

* The DMF would gain manpower and expertise in statistical and analytical techniques for reducing data and in refining sampling approaches.

* Graduate students, faculty and the DMF would benefit through collaboration on research projects, and through the use of additional sampling problems and data sets in training students. This would provide a low-cost solution to the understaffing problem.

* Academic scientists could use historical and continuing DMF baseline data for enhancing outside funding opportunities (e.g., Wallop-Breaux. Saltonstall-Kennedy, National Science Foundation).

* Decreased duplication of effort and facilities.

A Cooperative Fisheries Research Institute would set an unprecedented example of how state and university researchers could effectively address issues critical to North Carolina, while simultaneously training students to deal with future problems. Moreover, perceived barriers to collaboration between state and university researchers would be reduced, and problem solving would become much more efficient. We view this as a "win-win" solution.

Eventually, the infrastructure and location for such an institute could be the new "Center for Marine Science & Technology" (CMAST), which will be located next to Carteret Community College in Morehead City. The CMAST facility will be adjacent to the Morehead City DMF office, which currently houses the data management group for the DMF. Moreover, the CMAST facility will serve as a receiving station for real time, *in situ* water quality sensors located throughout the CAPES, as well as for remotely sensed information on water temperature, turbidity and primary productivity. Thus, locating a Fisheries Center within the CMAST facility would greatly facilitate integration of water quality and hydrodynamic analyses, with ongoing fisheries data analysis efforts, thereby increasing our ability to partition natural versus anthropogenic impacts on fisheries populations.

Conclusion

Many of the concerns raised and recommendations made in this report are applicable to numerous commercially important species in NC. In addition to the blue crab, program's 120 and 195 sample a variety of economically important species such as spot, croaker, weakfish, and summer and southern flounder. Thus, initial station stratification schemes and data analyses can probably be applied to data sets for these and other species captured in program's 120 and 195. The specific objectives addressed in this study should serve as a guide to future efforts in evaluating fisheries resource data collection, analysis and availability. Finally, several of the recommendations made in this study are similar to recommendations made in 1989 by Street and Phalen (1989) (e.g., "allocate the time and resources needed to conduct (stock assessment) analyses"). It is critical that these recommendations be followed by action.

References

Caddy, J. F. (ed.). (1989). *Marine Invertebrate Fisheries: Their Assessment & Management.* John Wiley & Sons, Inc. New York. 752 pp.

Casey, J. F., B. Daugherty, G. Davis and J. H. Uphoff, Jr. (1991). Blue crab management project: stock assessment of the blue crab in Chesapeake Bay, 1 July 1990 - 30 September 1991. Maryland Dept. Nat. Res., 22 pp.

Coale, J. S., R. A. Rulifson, J. D. Murray, and R. Hines. (1994). Comparison of shrimp catch and bycatch between a skimmer trawl and an otter trawl in the North Carolina inshore shrimp fishery. North Amer. J. Fish. Management 14:751-768.

Draper, N. and H. Smith (1981). *Applied Regression Analysis*, Second Edition. John Wiley & Sons, Inc., New York, 709 pp.

Eggleston, D. B. (1990). Behavioural mechanisms underlying variable functional responses of blue crabs, *Callinectes sapidus* feeding on juvenile oysters, *Crassostrea virginica*. J. Anim. Ecol. 59:615-630.

Gulland, J. A. (1983). *Fish Stock Assessment, A Manual of Basic Methods*. John Wiley & Sons, Inc., New York. 223 pp.

Gunderson, D. R. (1993). *Surveys of Fisheries Resources*. John Wiley & Sons, Inc. 248 pp.

Hilborn, R. (1992). Current and future trends in fisheries stock assessment and management. S. Afr. J. Mar. Sci. 12:975-988.

Hilborn, R. and C. J. Walters. (1992). *Quantitative Fisheries Stock Assessment: Choice, Dynamics & Uncertainty*. Chapman & Hall, Inc. New York. 570 pp.

Lipcius, R. and W. A. Van Engle. (1990). Blue crab population dynamics in Chesapeake Bay: variation in abundance (York River, 1972-1988) and stock-recruit functions. Bull. Mar. Sci. 46:180-194.

McKenna, S. and A. H. Clark. (1993). An examination of alternative fishing devices for the estuarine shrimp and crab trawl fisheries. NC Division of Marine Fisheries Project 93-11. 33 pp.

Morisita, M. (1959). Measuring of interspecific association and similarity between communities. Mem. Fac. Sci. kyushu Univ. Ser. E., Biol. 3:65-80.

Peterson, C. H. (1990). On the role of experimentation in resource management: Managing fisheries through mechanistic understanding of predator feeding behavior. Pages 821-846 in R. N. Hughes (ed.) *Behavioral Mechanisms of Food Selection*, NATO ASI Series, Vol. G 20, Springer-Verlag, Berlin.

Peterson, C. H. (1993). Improvement of environmental impact analysis by application of principles derived from manipulative ecology: Lessons from coastal marine case histories. Australia J. Ecol. 18:21-52.

Phillips, B. F. (1986). Prediction of commercial catches of western rock lobster, *Panulirus cygnus*. Can J. Fish. Aquat. Sci. 43:2126-2130.

Rothschild, B. J. (1986). Dynamics of Marine Fish Populations. Harvard University Press, Cambridge, MA 277 pp.

Ross, S. W. and S. P. Epperly. (1985). Utilization of shallow estuarine nursery areas by fishes in Pamlico Sound and adjacent tributaries, North Carolina. Pages 207-233 in: A. Yanez-Arancibia (ed.). *Fish Community Ecology in Estuaries and Coastal Lagoons: Towards an Ecosystem Integration.* UNAM Press, Mexico.

Speir, H. et al. (1995). Chesapeake Bay blue crab management plan. Maryland Dept. of Nat. Res. 66 p.

Street, M. W. and P. S. Phalen. (1989). Scoping study of data requirements for fisheries stock assessment in North Carolina. NC Division of Marine Fisheries, A/P Project 89-02, 42 pp.

Underwood, A. 1981. Techniques and analysis of variance in experimental marine biology and ecology. Oceanogr. Mar. Biol. Ann. Rev. 19:513-605.

Van Engle, W. A. (1958). The blue crab and its fishery in the Chesapeake Bay, Part I, reproduction, early development, growth and migration. Comm. Fish. Rev. 20:6-17.

Van Heukelem, W. F. (1991). Blue crab, *Callinectes sapidus*. *In*: Funderbunk, S. L., J. A. Mihursky, S. J. Jordan, and D. Riley (eds.). Habitat requirements for Chesapeake Bay resources. Chesapeake Bay Program, Annapolis, Maryland.

Tables

Table 1.

Historical and Current NCDMF Blue Crab Databases and Programs

Program No.	Program Name	Program Objective
120	Juvenile Stock Assessment	Determine the relative abundance of key estuarine species
190	Pamlico River Survey	Determine the relative abundance of blue crabs, and monitor effects of tailbag size on bycatch
195	Pamlico Sound Survey	Determine the distribution, movement, relative abundance, and size of estuarine species
471	Pamlico River Blue Crab	Characterize the commercial crab pot and trawl fisheries and conduct delayed harvest mortality rates
532	Blue Crab Morphometric Study	Assess geographic variation in cull ring peeler crab retention
540	DMF Crab Trawl Sampling	Determine the distribution and abundance of the blue crab in estuarine areas

Table 2.

General Recommendations Regarding the NCDMF Program Narratives

1. The audience (e.g., layman, fisheries managers, data analysts) for which the program narratives are written must be clearly defined.

2. Explicit, testable hypotheses must be stated.

3. Hypotheses should be followed by sufficiently detailed analytical approach(es).

4. Specific response variables, factors, and related variables (covariates) must be provided.

5. Potential concerns and biases for a specific sampling approach must be identified.

6. Application of sampling program to management needs must be stated.

7. Priority for analysis and subsequent reporting should be stated and updated.

These recommendations are aimed at facilitating access, analysis and interpretation of databases by researchers both within and outside of the DMF.

Table 3.

A. Strengths and Weaknesses of Program 120 (Initiated in 1970)

Gear Types: 4 m Otter-Trawl w/ 0.64 cm mesh in shallow water
6 m Otter-Trawl w/ 2.0 cm mesh in deeper water

1. Potential habitat-specific biases in gear selectivity are unknown.

2. An increase in tickler chain size between 1970-78 increased catchability.

3. Station selection was non-random and unstratified; Trawls within stations are not replicated but repeatedly sampled.

4. Unknown whether sampling stations were subject to commercial trawling until 1978.

5. Towing speed, distance, and time was not standardized to 1 min. = 75 yds. until 1978.

6. Blue crabs were not separated into sexes or maturity until 1978.

7. The number of stations sampled ranged from 48-216.

8. Program 120 represents a reliable 18 year data set for certain core stations.

B. Strengths and Weaknesses of Program 195 (Initiated in 1987)

Gear Type: Double-rigged, 9.1 m "Mongoose" trawl w/ 1.9 cm mesh cod end

1. Stratified random sampling scheme with only 52 original stations (sampled in Mar., Jun., Sep., Dec.).

2. The spatial coverage is limited (e.g., no stations in Albemarle Sound, western shore of Outer Banks, etc.).

	Pamlico R.	Neuse R.	Pungo R.	6'-12'	'12
# of stations	4	4	3	18	30

3. Narrative provides a useful description of potential analytical approaches.

4. Useful annual summary table of data provided.

Appendices

Synopsis of Three NCDMF Blue Crab Surveys

These synopses are intended to provide examples of the types of information and detail required for program narratives that are written for researchers.

Ia. 471 DMF Pamlico River Blue Crab Fishery (APES) - Fishery Dependent

1. Program # and Name: 471 DMF Pamlico River Blue Crab Fishery (APES) - Fishery Dependent

2. Purpose: (i) To examine harvest rates and bycatch in the crab pot and crab trawl fishery. How will data be applied to management? Will harvest rates from fishery-dependent data be compared with fishery-independent data collected in a similar manner from similar locations? This would be important for standardizing fishery-dependent CPUE for use in stock forecasting. Would culling practices be changed if bycatch rates were positively correlated with them?

3. Hypotheses: None

4. Target Population: Pamlico River Estuary

5. Spatial Distribution of Sampling: During 1990-91?. Geographic locations for each pot were recorded but not provided in narrative? What were general locations? Habitat types and depths unknown??

6. Gear Used & Response Variables: (i) crab pots with variable location, size, and number of cull rings; and (ii) trawls with variable headrope lengths, tow times and speeds, mesh sizes, etc. Any way to standardize commercial gear types?? How were pots chosen from total to subsample? Haphazard? Were all trawls sampled? CPUE for pots = crabs per soak time per pot? What about trawl CPUE? Crabs per tow time? Crab weight per tow time? Was trawl CPUE adjusted for different net specifications and tow speeds? Bycatch CPUE = crabs and crab weight per tow time? Finfish total abundance and total weight per tow time? Fish species abundance and weight per tow time? What was fate of finfish bycatch? Death or return? How was misc. category going to be analyzed and, if so, what information will it provide? Can habitat type be inferred from misc. category? Were cull rings standardized? What was cull-ring size? How are response variables and covariates replicated?

7. Related Covariates: tow time, net specifications, towing speed, starting and stopping coordinates (was geographic location entered into data base-related habitat types, depths, etc.), market conditions?, culling practices? What are "daily fishing activities" composed of in logbooks?

8. Temporal Distribution of Sampling: Crab trawling, November-May; Crab Pots, April-October

9. Analysis, Reports or Publications: APES Report No. 92-08. DMF Biological Database. However, data from objective (i) analyzed spatially and temporally w/ CPUE and percent bycatch as response variables. Summary tables are available. No publications.

10. Additional Comments: Fishermen maintained logbooks in which they recorded number of pots fished and total catch. Harvest rates analyzed as a function of what? (market conditions?, culling practices?, related covariates from (7.) ????, Geographic locations recorded in logbook. Not replicated over different seasons! (e.g., high harvest rates at a particular location and time may not be similar across years). Bycatch rates analyzed as a function of what? (culling practices, market conditions, covariates, gear type, etc.)???

Ib. 471 DMF Pamlico River Blue Crab Fishery (APES) - Fishery Dependent
1. Program # and Name: 471 DMF Pamlico River Blue Crab Fishery (APES) - Fishery Dependent

2. Purpose: (ii) To examine the physical injury and immediate mortality of blue crabs in the pot and trawl fishery. How does injury affect growth, mating success, survival? Are injury estimates used to adjust estimates of mortality? How will information on frequency of injury and mortality be used by management? Change or standardize culling practices? Link enforcement of bycatch to market conditions? Relationship between injury and gear type? What about impact of DO, Harmful Algal Blooms, etc. to harvest rates, bycatch, and injury? Related information on ambient water quality parameters available?

3. Hypotheses: None

9. Analysis: Summary Tables for each gear type, with monthly damage and mortality by number and percent were provided. No publications.

Additional Comments: Inferences regarding "old" injuries weak at best. Crabs may have been damaged from natural causes, or damaged by fishing practices. Data collection suggests categorical modelling approach with "minor" vs. major" damage categories. Ditto comments above for part Ia. At least 25% of samples were examined for minor vs. major damage; what samples were processed and how were they chosen?

Ic. 471 DMF Pamlico River Blue Crab Fishery (APES) - Fishery Dependent
1. Program # and Name: 471 DMF Pamlico River Blue Crab Fishery (APES) - Fishery Dependent

2. Purpose: (iii) To examine the level of delayed mortality of blue crabs in the pot and trawl fishery. This project was subcontracted out to ECU, Dr. Margie Gallagher, PI. Controlled laboratory experiments were conducted. Will estimates of mortality associated with injury be used to adjust overall mortality estimates for surplus biomass predictions?

3. Hypotheses: unknown; no narrative provided by Gallagher.

7. Related Covariates: temp., sal., DO, ammonia, chlorine, nitrate and nitrite, crab size and sex?, Degree of injury? Gear type? Response variable is presence of dead vs. alive, noted twice daily for 14 d.

IIa. 540 DMF Crab Trawl Sampling

1. Program # and Name: 540 DMF Crab Trawl Sampling

2. Purpose: To collect stock assessment information (i.e., dist., abund., recruitment?, nursery utilization?, growth of blue crabs

3. Hypotheses: None

4. Target Population: Pamlico Sound

5. Spatial Distribution of Sampling: 1980 four sites were chosen in the extreme southwest portion of Pamlico Sound (Rose Bay, Pungo River, Jones Bay, Broad Creek). In 1983, stations were added in N. Pamlico Sound area to include Pamlico River and Stumpy Pt. Bay. Unclear on how sites were chosen or why these particular sites? Also unclear on how many stations per site? What was rationale for station location or sample size? Unclear on which stations were in sand or mud, shallow or deep, or upper vs. lower portions? No indication of seagrass vs. unstructured habitats sampled? Was there replication at a particular station, or do stations serve as replicates for a particular tributary or location?

6. Gear Used: (i) 10.5-ft. otter trawl w/ 1/4 in. mesh for 1 min.; (ii) 26-ft. otter trawl with 2 in. mesh and 3/4 in. tailbag (= "wing net"?) for 10 min.? Why different gear types? gear efficiency in different habitat types? Vulnerability of different crab size-classes to different gear types? What were the response variables being measured? Juvenile and adult crab CPUE or crab density? Ratio of males to females? Frequency of disease? Were trawls pulled against tidal current? Were tidal currents even important?

7. Related Covariates: Bottom and surface temperature and salinity only? Why surface measures? What about DO?

8. Temporal Distribution of Sampling: (i) 10.5 ft. otter trawl- Monthly from August through November 1980-86? (1986 April-November only); and (ii) wing-net- monthly from March-November 1980-86? (1986 April-November only).

9. Analysis, Reports or Publications: None

10. Additional Comments: Is this an ongoing program since 1986? Seven-year time series has the potential for examining recruit-stock relationships, as well as correlations with physicochemical parameters! Critical need to take DO samples, assess habitat- and crab-size-specific gear biases, and block or stratify sampling approach.

FISHERIES MORATORIUM RESEARCH REPORTS

N.C. Sea Grant College Program

June 6, 1996

When the Fisheries Moratorium was enacted in 1994 by the N.C. General Assembly, the act specified that N.C. Sea Grant College would have studies completed to address priority questions identified by the Moratorium Steering Committee. The following is a list of the final reports resulting from those studies:

Eggleston, D.B. and S. McKenna. 1996. Evaluation of Fisheries Resource Data Collection, Analysis and Availability: An Example Protocol Using the Blue Crab. North Carolina Sea Grant College, Raleigh, NC. Report SG96-01, 23 p.

Garrity-Blake, B.J. 1996. To Fish or not to Fish: Occupational Transitions within the Commercial Fishing Community of Carteret County, NC. North Carolina Sea Grant College, Raleigh, NC. Report SG96-06 (ICMR 9605), 24 p.

Gordon, W.G. and B.L. Griswold. 1996. An In-Depth Administrative Review of the North Carolina Division of Marine Fisheries and the North Carolina Marine Fisheries Commission. North Carolina Sea Grant College, Raleigh, NC. Report SG96-09, 43 p.

Griffith, D. 1996. Impacts of New Regulations on North Carolina Fishermen: A Classificatory Analysis. North Carolina Sea Grant College, Raleigh, NC. Report SG96-07 (ICMR 9606), 110 p.

Griffith, D. and R.A. Rulifson. 1996. Characterization of the North Carolina Recreational Shrimp Trawl Fishery. North Carolina Sea Grant College, Raleigh, NC. Report SG96-07 (ICMR 9604), 18 p.

Johnson, J.C. and M.K. Orbach. 1996. Effort Management in North Carolina Fisheries: A Total Systems Approach. North Carolina Sea Grant College, Raleigh, NC. Report SG96-08 (ICMR 9607), 155 p. + 4 Appendices.

Single copies may be obtained by contacting the N.C. Sea Grant College (Box 8605, NCSU; Tel (919) 515-2454) in Raleigh (27695) or the N.C. Division of Marine Fisheries (Box 769; Tel (919) 726-7021) in Morehead City (28557).

NOTE: *If you would like a copy of the Appendices for the Johnson* and Orbach report (96-08), please call or write for your copy.