Review of "Status of the Eastern Oyster (*Crassostrea virginica*)"

Submitted to:

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Submitted by:

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EXECUTIVE SUMMARY

Terra Environmental Services, Inc. (Bruce Barber) was contracted by the Center for Independent Experts, University of Miami, to review a draft report on the status of the eastern oyster, *Crassostrea virginica*, written in response to a petition to list *C. virginica* as either threatened or endangered under the Endangered Species Act. The report, written by a Biological Review Team (BRT) organized by the NOAA Fisheries Service, was found to be generally complete and accurate.

Only minor revisions and suggestions for improvement were made, as described in this report. Overall, the species delineations were supported by the information presented. The report included the best scientific and commercial information available on the species and threats to it and its habitat. Conclusions drawn were sound and logically derived from the science. Opposing scientific studies were presented, where available.

The conclusion of the BRT "the long term persistence of eastern oysters throughout their range is not at risk now or in the foreseeable future" is correct based on currently available information.

1.0 Background

In response to a petition to list the eastern oyster, *Crassostrea virginica*, under the Endangered Species Act (ESA), NOAA Fisheries Service organized a Biological Review Team to conduct a review of the status of the species. Even though the petition was later withdrawn, NOAA Fisheries Services decided to complete the status review, the contents of which were to include relevant information upon which the agency could have based its ESA determination, had the process continued.

As part of the status review process, the agency requires external reviews by three experts, to be provided by the Center for Independent Experts, University of Miami. Each reviewer was tasked with reading the draft status report and producing a written report, emphasizing his/her area(s) of expertise.

The Center for Independent Experts (University of Miami) subcontracted Terra Environmental Services, Inc. (Bruce Barber) to conduct a review of the final draft of "Status of the Eastern Oyster (*Crassostrea virginica*)" prepared by the Biological Review Team organized by the NOAA Fisheries Service.

2.0 Description of Activities

The following specific reviewer tasks were undertaken as described in the Statement of Work (included as Appendix A):

- Read and review the status review report.

- Specifically address the following points (at a minimum):
  - Are species and/or subspecies delineations supported by the information presented?
  - Does the report include and cite the best scientific and commercial information available on the species and threats to it and its habitat?
  - Are the scientific conclusions sound and derived logically from the results?
  - Where available, are opposing scientific studies or theories acknowledged and discussed?

- No later than October 2, 2006, each reviewer shall submit a written report of comments and conclusions. Each report shall be sent to Dr. David Die, via email at ddie@rsmas.miami.edu, and to Mr. Manoj Shivlani, via email at mshivlani@rsmas.miami.edu.

3.0 Summary of Comments

3.1 Responses to specific questions in Statement of Work

a. Are species and/or subspecies delineations supported by the information presented?

> *This was subsequently clarified by NOAA as follows: There is genetic information included in the status review report which indicates that there may be two distinct subspecies of Crassostrea virginica. Taxonomists have not yet named subspecies for C. virginica. However, due to problems that have arisen in other status reviews (e.g., killer whale), we felt that it was important that the status review team include all the genetic information available for the species. The team did not make a definitive decision as to whether subspecies exist. We wanted the peer reviewers to review and provide their expert opinion on the information in the document and whether there is sufficient evidence to suggest that there is distinct population structure within this species.*

There is no clear consensus from existing genetic research indicating the existence of subspecies within *C. virginica*. Depending on the approach used, locations sampled, and sample size, populations were found to be either genetically homogenous or differentiated into two (Atlantic and Gulf) or three (north Atlantic, south Atlantic, and Gulf) populations. Part of the problem may lie with the difficulty of defining a "subspecies" or even a "species" using modern genetic techniques. It is not obvious how this could be done or what the criteria for doing so would be. The extent to which shellstock movement throughout the range of *C. virginica* has affected population genetics is difficult to assess, but may also contribute to the lack of obvious genetic differentiation.

Another consideration is the fact that due primarily to the plasticity of the oyster shell and the influence of local environment on shell morphology, there are no quantifiable metrics that might be useful for differentiating subspecies (Carriker and Gaffney 1996). In contrast, the bay scallop, *Argopecten irradians*, has three recognized subspecies within its geographic range along the east coast of North America: *A. irradians irradians, A. irradians concentricus*, and *A.*

irradians amplicostatus; morphological features of the valves (the number of ribs, width to length ratio, and relative inflation) distinguish the subspecies (Clarke 1965).

Loosanoff and Nomejko (1951) recognized the existence of physiological races along the latitudinal range of *C. virginica*. Since that time, most physiological differences have been found to be related to differences in environmental conditions, and therefore not due to actual genetic differences (Gaffney 1996). Even though there is evidence that differences in the timing of reproduction between some populations is genetically based (Barber et al. 1991), the genetic bases for these differences are poorly understood (Gaffney 1996).

In summary, the existence of genetically distinct populations or subspecies along the geographical range of *C. virginica* has not been established to date. Genetic studies using allozyme and molecular techniques have provided conflicting results and there is no consensus on what constitutes a "subspecies". Shell morphological features are not useful for this species. Observed physiological differences between populations rarely have a genetic basis. Considerably more research will be needed to elucidate these relationships.

b. Does the report include and cite the best scientific and commercial information available on the species and threats to it and its habitat?

For the most part the report is a well written, complete and accurate assessment of available information. There are no obvious omissions. It is understood that the status report was not intended to be an exhaustive review of all the literature, but rather a summary of the most pertinent information relevant to the pending ESA listing. Primary authoritative literature has been included as well as more recent information from local managers.

The following clarification or expansions of certain topics (with pertinent references) are suggested to increase the accuracy and completeness of the report.

Page 5, Morphology: *C. virginica* is a eulamellibranch (gill filaments joined at regular intervals by tissue connections called interfilamental junctions) (Eble and Scro, 1996). This is a feature common to many species of Ostreidae, not just *Ostrea equestris*, as stated in the first sentence. The foot and the anterior adductor muscle are present only in larval stages. After metamorphosis, oysters completely resorb the foot and an anterior adductor muscle, resulting in the monomyarian condition (Kennedy 1996, Morrison 1996). These facts should be clarified.

Page 6: The morphological plasticity of adult shells should be referenced (e.g., Galtsoff, 1964). Figure 1 in the report could be enhanced to illustrate this plasticity, much like Figures 21 and 22 in Galtsoff (1964).

Page 6, Reproduction: More precisely, oysters are dioecious alternate hermaphrodites, meaning that sex reversal can occur, but that an individual is either a male or a female at any time (Thompson et al. 1996).

Page 6-7, Larval Settlement: Larval "development" includes the various larval stages. "Metamorphosis" occurs only after settlement. It should also be noted that the rate of larval development is highly temperature dependent (Andrews 1979)

Page 7, Environmental Tolerances: Effects of high temperature on mortality are exacerbated by low salinity caused by rainfall events (Shumway 1996)

Page 7, Growth and Feeding: It should be noted that growth rate is highly dependent on temperature and food supply. As a result, growth rate generally decreases with increasing latitude.

Page 10, *Water Filtration*: Oysters produce biodeposits consisting of both feces and pseudofeces. Pseudofeces is physiologically defined as consisting of particles that have been trapped (filtered by gill cilia), combined with mucous, transported toward the mouth, but rejected by the palps prior to being ingested. Feces are comprised of material ejected from the anus after being filtered, ingested, and digested in the stomach and intestinal tract. These biodeposits play an important ecological role by making carbon available to the benthos and microbial food webs through the process of benthic-pelagic coupling (Dame et al, 1984).

Page 11, paragraph 3: Please include appropriate references.

Page 11, paragraph 4: Oysters in the southeastern U.S. are found primarily in intertidal locations because predation is reduced compared to subtidal locations.

Page 14, line 3: Define "gardner".

Page 14, Overview of Genetic Markers: Define "marker" and include in glossary.

Page 16, para. 2: Use of the word "story" implies fiction. Substitute with "interpretation"

Page 18, Other Cases of Population…: Would it be useful to use examples of other marine bivalve species (e.g., *Argopecten irradians* and *Mercenaria spp*.) distributions along the east coast of North America? Both have geographic ranges similar to that of *C. virginica*.

Page 14, -mariculture: What are these "inhibitory waste products"? Please include references.

Page 14, -eutrophication: Supply references for macro-algal smothering of oyster beds.

Page 26, last paragraph: To what extent has the effect of thermal addition on oyster populations been documented? Are there any references that can be cited or is this just hypothetical? For example, Quick (1971) found in controlled experiments that elevated temperature resulted in altered glycogen metabolism and gametogenesis as well as tissue damage.

Page 29-30, "change in coastal use": This trend is real and should be documented. For example, U.S. coastal counties comprise 17% of land area, but are inhabited by 53% of the

population; by the year 2008, coastal county population is expected to increase by approximately 7 million (Crossett et al. 2004).

Page 33, Rhode Island: What is the current status of oyster aquaculture in Rhode Island?

Page 34, line 1: When did importation of seed oysters reach 750,000 bushels?

Page 34, line 9: The first mention of MSX should include its causative agent, *Haplosporidium nelsoni*; similarly, *P. marinus* should be *Perkinsus marinus* (DERMO)

Page 38: The first mention of CPUE should include "catch per unit effort".

Page 39, *Canadian Maritimes*: Please include the year(s) of maximum and minimum landings.

Page 44, paragraph 1: Marine bivalves do not have a true immune (antigen-antibody) system. The more general term, "defense" should be used.

Page 44, paragraph 2: This should be slightly reorganized for clarity (see marked version of report); add Burreson and Andrews (1988).

Page 45, paragraph 1: A primary example of how proliferation of MSX and resultant mortality is controlled by environmental salinity is provided by Barber et al. (1997).

Page 45, paragraph 2: Effects of MSX on oyster energy metabolism and fecundity are documented in Barber et al. (1988a, 1988b).

Page 52: What are the ranges of *Aureococcus anophagefferens* and *Alexandrium monilatum*?

Page 56, Quantitative Stock Assessments: Researchers at the Virginia Institute of Marine Science, in collaboration with the Virginia Marine Resources Commission have been conducting quantitative estimates of oyster standing stock in the Virginia portion of Chesapeake Bay since 1993 (see Mann et al (2004) for details). This information should be included here.

Page 67, summary bullet 3: It is not clear how this was derived. According to survey questions 9 and 10, most populations are considered to be stable. Does it have to do with the fact that there are no (or few) long term quantitative stock assessments from which to assess population stability? Please clarify.

c. Are the scientific conclusions sound and derived logically from the results?

Yes (see comments above and marked version of report).

d. Where available, are opposing scientific studies or theories acknowledged and discussed?

Yes (see comments above and marked version of report). The differing results and conclusions regarding the population genetics of *C. virginica* are summarized appropriately. There is very little else on which experts disagree.

3.2 Editorial revisions

A marked copy of the status report is included as Appendix B. Alterations are intended to correct typographical errors or improve the readability of the document. Included comments refer to statements made previously.

4.0 Conclusions and Recommendations

The draft status report reviewed provides a comprehensive overview of the current status of the eastern oyster, *Crassostrea virginica*, with respect to species biology and analysis of the ESA's five factors, including: habitat threats, over-utilization, predation and disease, regulatory mechanisms, and other impacts. The BRT is correct to conclude that "the long term persistence of eastern oysters throughout their range is not at risk now or in the foreseeable future".

There clearly has been a reduction in populations of *C. virginica* throughout its range that has resulted in the loss of a fisheries (economic) resource as well as considerable ecological function in some estuaries. Most population reductions are the result of long-term overharvesting, which in addition to reducing standing stock and reproductive capacity also has resulted in habitat alteration. Since about 1960, diseases have further reduced declining commercial populations. In addition, changes in coastal land use have altered estuarine water quality. Even though the commercial status of the species has been reduced, the species itself has remained viable and current oyster populations appear to have stabilized. Eastern oysters are adapted to estuarine conditions, including continually changing temperatures and salinities, and impacted water quality. Their high fecundity enables them to withstand a myriad of predators and diseases. Thus even though there may not be enough larger oysters to support a commercial fishery, there are still reproducing populations of oysters.

As local commercial populations are depleted, aquaculture of local stocks will increase to meet demand. Hatchery production utilizing selected strains will increase intensive (hatchery to market) operations.

The overall range of the species has not changed. Studies on population genetics do not clearly support the existence of isolated, genetically distinct sub-populations. Only broad regional differences have been found, varying to some extent depending on the technique or genetic marker utilized.

Restoration of oyster reefs for either commercial production or ecological services is unlikely to be cost effective, given the continuing (if not increasing) impact of parasitic diseases caused by *H. nelsoni* and *P. marinus* and the scale of such an effort that would be required to alter water

quality in any given estuary. Utilization of hatchery-produced seed for restoration purposes will be similarly ineffective.

5.0 References Cited in this Report

Andrews, J.D. 1979. As cited in Status Report.

Barber, B.J., S.E. Ford and H.H. Haskin. 1988a. Effects of the parasite MSX (*Haplosporidium nelsoni*) on oyster (*Crassostrea virginica*) energy metabolism. I. Condition index and relative fecundity. J. Shellfish Res. 7: 25-31.

Barber, B.J., S.E. Ford and H.H. Haskin. 1988b. Effects of the parasite MSX (*Haplosporidium nelsoni*) on oyster (*Crassostrea virginica*) energy metabolism. II. Tissue biochemical composition. Comp. Biochem. Physiol. 91A: 603-608.

Barber, B.J., S.E. Ford and R.N. Wargo. 1991. Genetic variation in the timing of gonadal maturation and spawning of the eastern oyster, *Crassostrea virginica* (Gmelin). Biol. Bull. 181: 216-221.

Barber, B.J., R. Langan, and T. Howell. 1997. *Haplosporidium nelsoni* (MSX) epizootic in the Piscataqua River Estuary (Maine/New Hampshire, U.S.A.). J. Parasitol. 83: 148-150.

Burreson, E.M. and J.D. Andrews. 1988. Unusual intensification of Chesapeake Bay oyster diseases during recent drought conditions. Pages 799-802 in Proceedings of OCEANS '88. A Partnership of Marine Interests.

Carriker, M.R. and P.M. Gaffney. 1996. As cited in Status Report.

Clarke, A.H. 1965. The scallop superspecies *Aequipecten irradians* (Lamarck). Malacologia 2: 161-188.

Crossett, K.M., T.J. Culliton, P.C. Wiley and T.R. Goodspeed. 2004. Population Trends Along the Coastal United States: 1980-2008. National Oceanic and Atmospheric Administration. 54 p.

Dame, R.F., R.G. Zingmark and E. Haskin. 1984. Oyster reefs as processors of estuarine materials. J. Exp. Mar. Biol. Ecol. 83: 239-247.

Eble, A.F. and R. Scro. 1996. General anatomy. Pages 19-73 in Kennedy, V.S., R.I.E. Newell and A.F. Eble (eds.). The Eastern Oyster *Crassostrea virginica*. Maryland Sea Grant, College Park.

Gaffney, P.M. 1996. Biochemical and population genetics. Pages 423-441 in Kennedy, V.S., R.I.E. Newell and A.F. Eble (eds.). The Eastern Oyster *Crassostrea virginica*. Maryland Sea Grant, College Park.

Galstoff, P.S. 1964. As cited in Status Report.

Kennedy, V.S. 1996. As cited in Status Report.

Loosanoff V.L. and C.A. Nomejko. 1951. Existence of physiologically-different races of oysters, *Crassostrea virginica*. Biol. Bull. 101: 151-156.

Mann, R., M.J. Southworth, J.M. Harding and J. Wesson. 2004. A comparison of dredge and patent tongs for estimation of oyster populations. Journal of Shellfish Research 23: 387-390.

Morrison, C.M. 1996. Adductor and Mantle musculature. Pages 169-183 in Kennedy, V.S., R.I.E. Newell and A.F. Eble (eds.). The Eastern Oyster *Crassostrea virginica*. Maryland Sea Grant, College Park.

Quick, J.A. (Ed.) 1971. A preliminary investigation: the effect of elevated temperature on the American oyster *Crassostrea virginica* (Gmelin).

Shumway, S.E. 1996. As cited in Status Report.

Thompson, R.J., R.I.E. Newell, V.S. Kennedy and R. Mann. 1996. As cited in Status Report.

6.0 Appendices

A Statement of Work

B Marked copy of Status Report

Subcontract between the University of Miami and Terra Environmental Services Inc. (Bruce Barber)

STATEMENT OF WORK

Background

In January 2005, NOAA's National Marine Fisheries Service (NOAA Fisheries Service) was petitioned to list eastern oyster (*Crassostrea virginica*) under the Endangered Species Act (ESA). As required, NOAA Fisheries Service reviewed the petition and made a positive 90-day finding determining that the information in the petition and otherwise available to the agency indicated that the petitioned action may be warranted. As a result of the positive finding, the agency was required to conduct a review of the status of the species to determine if listing under the ESA is warranted.

NOAA Fisheries Service organized a biological review team (BRT) consisting of federal and state biologists to assemble the facts. In so doing, the team was instructed to organize and review the best available scientific and commercial information on eastern oysters and to then present its factual findings to the agency in a status review report. The report did not need to be based on consensus – opposing individual viewpoints were welcomed as long as the viewpoints were sound and based in science. Further, the report was not to contain any listing advice or to reach any ESA listing conclusions – such synthesis and analysis is solely within the agency's purview.

On Wednesday, October 19, 2005, NOAA Fisheries Service received a letter from the petitioner dated October 13, 2005 requesting the recall of the eastern oyster petition. In his letter, the petitioner indicated that his request to withdraw the petition was due to the public and industry's confusion over the petition and listing process. NOAA Fisheries Service accepted this request and ceased evaluation of the petition. However, a considerable amount of effort had been expended by the BRT at the point at which the withdrawal of the petition occurred. Also, the completed status review report is the most timely and comprehensive resource document for this species. As such, NOAA Fisheries Service determined that because the report is a useful tool in guiding future management decisions, the BRT should complete the status review report.

NOAA Fisheries Service is required to use the best available scientific and commercial data in making determinations and decisions under the ESA. The first question that must be addressed is what the appropriate species delineation is for consideration of conservation status. The ESA defines an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range," and a threatened species as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." A species may be determined to be threatened or endangered due to any one of the following factors:

(1) the present or threatened destruction, modification, or curtailment of its habitat or range;
(2) overutilization for commercial, recreational, scientific or educational purpose;
(3) disease or predation;

(4) the inadequacy of existing regulatory mechanisms; and
(5) other natural or manmade factors affecting its continued existence.

The scientific and commercial information contained in the status review should contain essential factual elements upon which the agency could have based its ESA determination. Accordingly, it is critical that the status review contain the best available information on the species and the threats, that all relevant information is identified and included, and that all scientific findings be both reasonable, and supported by valid information contained in the document. As such, the agency requires a peer review that focuses on the factual support and scientific methodology upon which the status review report is based.

Reviewer Responsibilities

The Center for Independent Experts shall provide three reviewers. Each reviewer's duties shall not exceed a maximum of seven days to read the status review report and, as needed, the scientific papers referenced therein. Each reviewer shall produce an individual written report, with emphasis on his/her area(s) of expertise. See Annex I for additional details on the contents and organization of the reviewer's reports. No consensus opinion (or report) will be required.

There are several primary issues related to this species that must be addressed. Reviewers with the following expertise are required to ensure the best available information has been utilized.

- Life history and population dynamics of eastern oysters
- Eastern oyster genetic, physiological, behavioral, and/or morphological variation throughout the species' range
- Eastern oyster habitat requirements
- Harvest
- Predation and disease
- Regulatory mechanisms for managing the species
- Other natural or manmade impacts affecting eastern oysters
- Aquaculture
- Conservation actions including restoration efforts and recovery activities

Each reviewer will be supplied with the status review report prepared by the biological review team. Any of the reports and papers cited in the status review report will be made available to the reviewers upon their request.

Specific Reviewer Tasks and Schedule

1. Read and review the status review report.
2. Specifically address the following points (at a minimum):
    a. Are species and/or subspecies delineations supported by the information presented?
    b. Does the report include and cite the best scientific and commercial information available on the species and threats to it and its habitat?
    c. Are the scientific conclusions sound and derived logically from the results?

   d. Where available, are opposing scientific studies or theories acknowledged and discussed?

3. No later than October 2, 2006, each reviewer shall submit a written report of comments and conclusions[1]. Each report shall be sent to Dr. David Die, via email at ddie@rsmas.miami.edu, and to Mr. Manoj Shivlani, via email at mshivlani@rsmas.miami.edu.

[1] Each written report will undergo an internal CIE review before it is considered final.

ANNEX I: REVIEWER REPORT GENERATION AND PROCEDURAL ITEMS

1. The reviewer report shall be prefaced with an executive summary of comments and/or recommendations.

2. The main body of the reviewer report shall consist of a background, description of review activities, summary of comments, and conclusions/recommendations.

3. The reviewer report shall also include as separate appendices the bibliography of materials provided for the review and all other documents cited in the report, and a copy of the statement of work.

Please refer to the following website for additional information on report generation: http://www.rsmas.miami.edu/groups/cimas/Report_Standard_Format.html.