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

Jason P. Curole
University of Southern California

Executive Summary

In 2006 NOAA's National Marine Fisheries Service (NMFS) received a petition to list the Eastern oyster (*Crassostrea virginica*) as either threatened or endangered under the Endangered Species Act, which was later withdrawn. Prior to the withdrawal of the request, the NMFS Biological Review Team (BRT) completed a report on the status of the Eastern oyster. I was asked to independently review this report and spent several days reading the report and the appropriate background material. These are my comments on selected aspects of the report.

The status report appears fairly complete in its current form. Independent fisheries population data are critical for determining the status of the Eastern oyster and the BRT cannot overstate the need for fisheries independent population assessments. I was asked to specifically address whether subspecies/species delineations are supported by the data presented in the report. The BRT should consider recognizing the Gulf and Atlantic populations as unique populations, if not subspecies at a stage of incipient speciation. Several threats to habitat loss were listed in the report, including future demographics/social changes along coastline. Additional data on habitat threats with respect to coastal demographics/social changes and their affect on the oyster fishery would help determine if these are a legitimate threat. Overutilization, although not identified as a major threat, has been identified as the primary cause of the decline in oyster stocks on the Eastern seaboard and should continue to be evaluated. To assess the status of Eastern oyster populations, a questionnaire was circulated to fishery managers and independent experts. The usefulness of this questionnaire is doubtful and true quantitative stock assessments are necessary. Monitoring of stock enhancement/conservation/restoration efforts is also imperative as a future need. Persistence of the Eastern oyster is not at risk now or in the foreseeable future, but additional population data are necessary to fully evaluate this conclusion.

Background

The Eastern oyster (*Crassostrea virginica*) is distributed along the North American coast from Canada to Galveston, Texas. The Eastern oyster is a bivalve with a free-swimming, pelagic larval stage and a sedentary adult stage, whereby adults are attached to hard, solid substrate. Despite once unimaginable population sizes, oyster populations have been reduced to a fraction of their former size on the Atlantic seaboard. This drastic reduction in population size is primarily due to overfishing, a concern identified as early as 1895 (Brooks 1895). Remaining populations have been devastated and restoration hindered by disease (primarily DERMO and MSX), which afflict the Eastern oyster and result in heavy mortality on Eastern seaboard populations. In addition, habitat degradation, due to removal of hard substrate through overutilization, hinders recovery. The decline in oyster populations is concomitant with the onset of hypoxia, anoxia and eutrophication in the Chesapeake Bay estuary (Jackson et al. 2001). Decline of this species in the Chesapeake Bay is associated with loss of ecosystem services and potential top-down control of community structure in estuaries, as filtering by oysters limits phytoplankton blooms and symptoms of eutrophication (Jackson et al. 2001).

In 2005, the National Marine Fisheries Service (NMFS) received a petition to list the Eastern oyster as a threatened species. Although this petition was withdrawn, the NMFS chose to complete the status review report of the Eastern oyster, which is mandated as part of the request for threatened species listing. This report covers aspects of the species biology, an analysis of the Endangered Species Act's (ESA) five factors, aquaculture, status of populations, conservation actions, research needs and conclusions.

On September 19, 2006, I was contacted by the Center for Independent Experts at the University of Miami and was requested to examine the status report and produce a review by October 2, 2006. My

responsibilities as a reviewer are to read the status report and the scientific papers referenced therein and produce an individual written report with an emphasis on my area of expertise. Specifically reviewers were asked to address the following points: 1) Are species and/or subspecies delineations supported by the information presented, 2) Does the report include and cite the best scientific and commercial information available on the species and threats to it and its habitat, 3) Are the scientific conclusions sound and derived logically from the results, and 4) Where available, are opposing scientific studies or theories acknowledged and discussed.

My training and/or expertise are in evolutionary genetics and genomics, general bivalve biology and aquaculture. My undergraduate and postgraduate work has focused nearly exclusively on bivalves, including the freshwater bivalves of North America and the Pacific oyster, *Crassostrea gigas*. My master's thesis dealt with population genetic structure in freshwater bivalves and my PhD with evolutionary genomics. I have had extensive training in population genetics and evolutionary genomics/genetics. In addition, my PhD tenure was in the lab of Dr. Thomas Kocher, whose primary biological focus is on speciation in East African cichlids; thus, although I have not worked on speciation specifically, I was exposed to extensive research in this area as part of the Kocher group. Following my PhD work I moved to the lab of Dr. Dennis Hedgecock and have been exposed to aquaculture work. Given my areas of training/expertise I have focused my review on points 1 (species/subspecies status), 3 (sound scientific conclusions) and 4 (opposing studies/theories).

Review Activities

Species biology

Overall, I found the section on species biology to be complete and accurate. Much of this basic work is complete, although there are still extensive gaps in knowledge of oyster biology. The report points out that biological surveys have not yet been conducted with appropriate sampling strategies to determine statistically reliable population numbers. This is a major gap in knowledge of the Eastern oyster and underpins a significant weakness in assessing the status of the Eastern oyster and in restoration/conservation efforts. The Biological Review Team (BRT) identified fishery independent surveys as a future need and I completely concur.

Population and genetic structure: Species/subspecies delineations

Specific reviewer task 2a requested that reviewers address whether species or subspecies delineation for the Eastern oyster is supported by the information presented. My interpretation of this request is that I address whether the Atlantic and Gulf populations of the Eastern oyster, as identified in Reeb and Avise (1990) for example, constitute separate species/subspecies. The biological review team is likely aware that designation of species status is a somewhat contentious practice in biology. Since Ernst Mayr's first effort to provide a species definition, numerous species concepts have been put forward. My perception is that the Biological Species Concept proposed by Mayr is still considered the most applicable species concept for diploid, sexually reproducing organisms (like the Eastern oyster). In reality, most species/subspecies delineations are based on distinct morphological or behavioral differences between individuals from different populations, although this probably represents a bias towards species delineations that are common in vertebrates. Relying solely on morphological or behavioral differences may lead to an inaccurate diagnosis, as physiological differences (which are much more difficult to diagnose) may be more important. I am unaware of any data, nor was any data presented in the status report, on the Eastern oyster that addresses morphological, behavioral or physiological differences between the Atlantic and Gulf populations of the Eastern oyster. Several

other species concepts do address genetic data and I will review the data presented in the status report in light of those concepts.

The status report accurately classified genetic data into two categories: frequency data and identity or sequence data. These two data types are treated under different species concepts, so I will address each data type separately. Frequency data was the first evidence presented with respect to population structure in the Eastern oyster and I will cover this data first. Principles of species concepts and my treatment thereof are based primarily on Coyne and Orr (2004).

Frequency data

Buroker (1983) presented the first genetic data on the Eastern oyster, examining numerous allozyme (or protein) loci and concluding that no population structure is present in the Eastern oyster. The status report indicates that failure to find genetic differentiation is an ambiguous result, which may be due to a variety of causes. Although I would refrain from labeling such a result ambiguous, the report is accurate in the necessity of addressing the discrepancy between allozyme and other data. Frequency data on three anonymous, nuclear loci presented by Karl and Avise (1992) strongly suggested that the Eastern oyster is differentiated into Atlantic and Gulf populations; this data is consistent with mitochondrial haplotype data presented by Reeb and Avise (1990) which I address below. Karl and Avise (1992) proposed balancing selection on the allozyme loci as a possible explanation for the discrepancy between the allozyme, mitochondrial and anonymous nuclear loci. Hare and Avise (1996) followed up on the work by Karl and Avise by examining allele frequencies along the eastern Florida coast. In addition to supporting the results of Karl and Avise, they pinpointed the cline in allele frequencies to the Cape Canaveral area. Hoover and Gaffney (2005) examined 4 nuclear nonanonymous loci and also found structure between populations, with an average Fst value of 0.083, which is substantial for marine populations.

It has been shown that the results observed by Buroker may have been an artifact of the method of analysis, although this analysis was not included in the status report. Cunningham and Collins (1994) showed that when the allozyme data are analyzed with alternate genetic distance and clustering algorithms, genetic structure is present within the Eastern oyster, although the breakpoint between Gulf of Mexico and Atlantic populations is not congruent with other data. Regardless, my conclusion is that both the allozyme data as analyzed by Cunningham and Collins (1994), the anonymous nuclear loci as reported by Karl and Avise and the nonanonymous loci presented by Hoover and Gaffney (2005) are congruent in suggesting two separate populations of oysters on the North American coastline.

McDonald et al. (1996) examined several anonymous nuclear loci in two populations of Eastern oyster and reported observing a lack of geographic differentiation. This study is not as thorough as Karl and Avise or Hare and Avise because only two populations were sampled. In addition, although the authors did not observe genetic differentiation as high as that of Karl and Avise, Fst values at several anonymous nuclear loci are in the 5-11% range, consistent with Hoover and Gaffney (2005). These Fst values are similar to those of many allozymes (see Table 2 in MacDonald et al. 1996) and as mentioned above, allozymes do show some support for population differentiation. One significant issue with studies of population structure in oysters using anonymous nuclear loci is null alleles. A null allele is an allele that is undetectable in a particular genotypic assay and results in inaccurate genotyping (see Hare et al. 1996 for a discussion of null alleles). The prevalence of markers that are not in Hardy-Weinberg equilibrium in MacDonald et al. (1996; see Table 1) is suggestive of null alleles and these results should be interpreted with caution.

The Genotypic Cluster Species Concept defines a species as “a [morphologically or genetically] distinguishable group of individuals that has few or no intermediates when in contact with other such

clusters" (Coyne and Orr, p.447, 2004). No data (that I know of or as presented in the status report) is available to address whether Atlantic and Gulf populations cluster morphologically and it is quite possible that differences between these populations (or any set of populations) could be physiological and would therefore not be recognized morphologically, but the gene frequency data on the Eastern oyster falls under this species concept. Using the clustering criteria, the Karl and Avise, Hare and Avise and Hoover and Gaffney data support a species/subspecies designation for the Gulf and Atlantic populations. The Buroker data as analyzed by Cunningham and Collins provide weaker support for species designation. The MacDonald et al. data are ambiguous because with only two populations clustering is not applicable.

Identity or sequence data

Reeb and Avise (1990) presented the first set of identity data (although they used RFLP, the data are analyzed by estimating sequence divergence from restriction profiles). Their data provided the first evidence for two distinct clades, an Atlantic and a Gulf clade separated by about 2.5% sequence divergence. This data is in congruence with data from other species (some mentioned in the report), which also show a phylogenetic breakpoint at the southern Florida coast. Not mentioned in the report are *Limilus polyphemus* (the horseshoe crab), *Cicindela dorsalis* (tiger beetle), *Ammodramus maritimus* (seaside sparrow), *Malaclemys terrapin* (diamond-back terrapin) and *Geukensia demissa* (ribbed mussel) which also show a phylogenetic breakpoint at Florida (see Avise 2000). The Reeb and Avise study was followed with work by Hare and Avise (1998) examining allelic sequences of the three anonymous nuclear markers. The status report indicates that these were the same loci used by Hare and Avise (1996) and Karl and Avise (1996). This is incorrect; only the CV-23 locus is shared by all three studies. The status report also indicates that Hare and Avise (1998) used SSCP to look for population structure. This is also incorrect; Hare and Avise used SSCP to identify heterozygotes, but these were then sequenced. None of the three loci examined by Hare and Avise (1998) provide evidence for two separate clades as identified by the mitochondrial data. Hare and Avise (1998) do mention that "although the phylogeny of haplotypes at the CV-32 locus does not distinguish Atlantic from Gulf oyster populations, the allele frequencies a this locus nearly do, and relatively few lineage extinctions would be required to produce a gene tree displaying reciprocal monophyly" (*ie.* a gene tree similar to the mitochondrial tree).

The Genealogical Species Concept (GSC) states that "a species is a basal, exclusive group of organisms all of whose genes coalesce more recently with each other than with those of any organisms outside the group, and that contains no exclusive group within it" (Coyne and Orr, p.467, 2004). Based on this strict definition the Gulf and Atlantic populations would not be considered separate species. This strict criteria (complete sorting at all loci) has been criticized and other cutoff levels have been proposed (*eg.* 50% of loci), but the Gulf and Atlantic would still not qualify as separate species under this reduced cutoff. It has been pointed out though that even under this criteria, species recognized as legitimate under other species concepts would not be recognized under the GSC. Taken individually the mitochondrial data provide support for species status, while the three anonymous nuclear loci do not. This incongruence is not surprising as mitochondrial DNA has an effective population size that is 25% of nuclear loci and we expect complete lineage sorting (*ie.* complete sorting of sequences into two distinct groups or clades as is the case for mitochondrial DNA in the Eastern oyster) to occur more rapidly for mitochondrial data. The incongruence of data here suggests that the Gulf and Atlantic populations have not been separate for long and may be in the initial stages of speciation (incipient species).

Conclusions

Biological species are often recognized by distinct morphological or behavioral differences between populations, although this approach may represent a bias towards vertebrates. To my knowledge Eastern oysters have not been examined with the specific goal of identifying morphological differences between populations. It is unclear whether morphological work would be fruitful, as any potential differences between the Gulf and Atlantic populations may involve physiologically relevant traits, which would be much more difficult to identify than morphological differences. The available genetic data suggest that the Gulf and Atlantic populations of the Eastern oyster are at a stage of incipient speciation and should probably be considered subspecies.

The BRT identified further genetic analysis of population structure as a future need. It is unclear what exactly additional population genetic data would provide towards clarification of species/subspecies status. Given the previous results of population genetic work, additional markers are likely to provide similar results, with significant allele frequency differences between populations but a lack of complete lineage sorting for sequence data. I am dubious that additional population genetic work with respect to species/subspecies status will provide results qualitatively different from the available data. I see further work in this area as less important than other identified needs.

Analysis of the ESA's five factors

The BRT covered habitat threats, overutilization, predation and disease, regulatory mechanisms and other natural and manmade impacts in this analysis. Overall these sections appear complete and coverage of the literature is fairly extensive.

Habitat

The section on habitat threats appears thorough and covers the numerous threats to habitat loss or degradation that are present. The section on coastal demographics/social changes does seem somewhat speculative though. I agree that there appears a current trend in increasing coastal development, but no hard data or references are presented in this section to justify concerns regarding these demographic/social changes. It is unclear whether these are the conclusions of the BRT, and if so what data they are based upon, or if this is speculation based on what appear to be social trends. Either way, this section would benefit from references or data supporting the speculation. If data is lacking on these trends and their effects on oyster fishery, then this should be identified as a gap in knowledge/future need in Section 8 (Research Needs).

Overutilization

The BRT provides extensive coverage of commercial utilization/harvesting at a state/regional level. The coverage of historical overfishing of oyster resources on the Eastern seaboard is lacking. In the discussion of harvesting, specifically along the eastern seaboard, when reference to fisheries catch was mentioned it was without exception declining. The BRT does point out that landings are a poor measure of population status, but my understanding of the fisheries experience is that declining catch is often a measure of a declining resource. The available data suggest that despite the strong emphasis on the role of disease in the decline of the Eastern oyster, overutilization resulting in extensive habitat degradation is a more significant factor in the Eastern oyster's decline (Rothschild et al. 1994). I recognize that disease is believed to be devastating oyster populations on the Eastern US seaboard, but I am skeptical that the continued decline in fisheries catch along the Eastern seaboard is not a bad omen for the fishery.

Conclusions

The report covers the extensive threats to the Eastern oyster, including habitat threats, disease and overutilization. I found the section on habitat threats to be thorough and extensive. Although other sections on habitat degradation were well referenced, I found the section on coastal demographics/social change to lack hard data or references that might bolster the argument for these factors as threats. My interpretation is that this results from a lack of data and it strikes me that this should be an area identified as a gap in knowledge/future need, although how important a future need is unclear. The report spends several pages reviewing the utilization of oyster populations along the Atlantic seaboard and Gulf of Mexico states, as well as in Canada and Mexico. This review presents an overall picture of fisheries decline, particularly on the Atlantic seaboard. Despite these declines and the strong evidence that the historical decline of the Eastern oyster is due to overutilization (*cf.* Rothschild et al. 1994) and not disease, overutilization arises as a minor concern. This strikes me as a disconnect between the data and the conclusions drawn from that data.

Status of Population

Quantitative stock assessments are limited for the Eastern oyster, with Rothschild et al. (1994) producing the first modern quantitative stock assessment for Chesapeake Bay. On a regional/state level quantitative stock assessments are also limited, but available assessments indicate that oyster stocks are likely being overutilized in nearly all areas. To assess the status of the Eastern oyster the BRT conducted a survey. Survey responses were sought from a single fishery manager and independent expert in order to avoid potential biases. I appreciate the attempt to obtain a balanced viewpoint regarding the status of the Eastern oyster, however Appendix III indicates that although all but 3 of the 17 resource managers responded to this survey, only about half of the independent experts responded. More troubling is the lack of responses from independent experts along the Atlantic seaboard, where the Eastern oyster fishery has a long history of overutilization.

In the questionnaire, respondents were asked if populations are stable based on fisheries dependent and fisheries independent data. Based on fisheries dependent data, 53% of oyster populations are deemed stable and 60% are deemed stable based on fisheries independent data. In the summary, the BRT concludes that "fisheries dependent data and independent data are insufficient to assess the stability of populations" (p. 76). Given the dearth of data available, I agree that assessing the stability of populations is difficult. This highlights a significant disconnect between figures 9 and 10 on p. 70, where respondents claim that over half of oyster populations are stable and the conclusions of the BRT. The lack of data to make the assessment of stable vs. unstable and the fact that over 50% of populations were deemed stable in the survey casts doubt on the value of the survey.

Conservation/Restoration

Conservation and restoration efforts are largely underway, primarily in the Chesapeake Bay area, but also along the Gulf of Mexico. Outside of the Chesapeake Bay area restoration efforts appear to be small scale and directed towards fishery restoration. In the Chesapeake Bay area the Army Corp of Engineers is a significant source of funding for oyster restoration.

One weakness of the restoration efforts as pointed out by the BRT is the lack of monitoring of restored reefs. One monitoring study that the BRT did not cover is that of Hare et al. (2006). Using genetic markers to assign spat to one of two reference populations, either DEBY or wild-caught, Hare et al. (2006) estimated that planted DEBY stocks contributed no more than 10% enhancement of 2002 recruitment in the Great Wicomico River. Additional monitoring of enhancement success should be identified as a future need.

Conclusions of the Report

The BRT concluded that the long term persistence of the Eastern oyster is not at risk now or in the foreseeable future. I concur with this assessment, but I think it is imperative that resource managers obtain a better estimate of the status of the resource. In particular, long-term fishery independent monitoring of populations should be a primary goal of future work

Summary of Comments

The Eastern oyster is distributed along the North American coast from Canada to Galveston, Texas. Like other cupped oysters, the Eastern oyster has a pelagic larval stage, followed by settlement onto hard substrate and a sedentary adult stage. The Eastern oyster has been harvested for hundreds of years, but harvesting peaked in the late 19th century and then rapidly declined. In 2006, a request was put forward to review the status of the Eastern oyster with respect to the Endangered Species Act (ESA). Although this request was withdrawn, the NMFS prepared a status report for the Eastern oyster and requested independent review of this report. As an independent scientist with training in genetics, aquaculture and oyster biology I was asked to review this proposal.

Overall the proposal appears complete, addressing the species biology, the ESA's five factors, aquaculture efforts, the status of populations, conservation actions and research needs. My primary comments are the following:

1. The biological review team identified fishery independent surveys as a future need and I completely concur.
2. The NMFS asked that reviewers specifically address species and/or subspecies status of the Eastern oyster. I thoroughly reviewed the available data with respect to scientific species concepts. I found that the regularly observed differences in allele frequencies between the Atlantic and Gulf populations, as well as the complete sorting of mitochondrial DNA lineages supports the Atlantic and Gulf populations as separate species/subspecies. The incomplete sorting of nuclear lineages does not support species status. All data is consistent with the hypothesis that Atlantic and Gulf populations may be at the incipient or early stages of speciation and should probably be considered subspecies. The BRT identified further genetic analysis as a future need, but it is unclear whether additional genetic data will resolve the species/subspecies question.
3. The section on habitat threats appears complete, although the section on coastal demographics/social changes seems speculative. If this is considered a real threat, then studies on this aspect of the oyster fishery should be identified as a future need.
4. The BRT provided extensive coverage of commercial utilization at a regional level. Despite the long history of overutilization in the oyster fishery, overutilization is not identified as a significant threat. As recently as 1990, habitat destruction due to overutilization was identified as a cause of decline in the oyster fishery, and landings as reported in the status report are declining (particularly on the eastern seaboard). These data suggests that overutilization should be considered further. The possibility of continued overutilization only amplifies the significance of addressing the lack of fisheries independent population data.
5. To assess the status of populations the BRT primarily relied upon a questionnaire. The lack of independent experts who replied to this questionnaire, particularly on the eastern seaboard, undermines it usefulness. Responses to the questionnaire indicated that based on fisheries independent and fisheries dependent data most populations of the Eastern oyster are stable. The

complete lack of any data upon which these conclusions might be based and the reports of declining landings cast doubts on the value of this survey.

6. The BRT identified the lack of monitoring as a weakness in conservation/restoration efforts. The only data I am aware of with respect to monitoring restoration is by Hare et al. (2006) which indicate that planted DEBY stocks contributed no more than 10% enhancement of 2002 recruitment in the Great Wicomico River. Additional monitoring of restoration efforts should be identified as a future need.
7. The BRT concluded that the long term persistence of the Eastern oyster is not at risk now or in the foreseeable future. Although it is difficult to make this assessment given the lack of population data, I concur.

The Terms of the SOW

a) All data is consistent with the hypothesis that Atlantic and Gulf populations may be at the incipient or early stages of speciation and should probably be considered subspecies. (see summary comment 2 for details)

b) The report appears to cite the best available evidence on threats to the Eastern oyster. There are significant gaps in knowledge on threats to the Eastern oyster. In particular, the section on coastal demographics/social change lacks any hard data (see summary comment 3) and the questionnaires are of dubious use in establishing the status of oyster populations (see summary comment 4).

c) The scientific conclusions of the report seem for the most part sound and logically derived. The one exception is the classification of overutilization as an insignificant threat. Historical data suggest that overutilization has played a significant role in the decline of the species and no data is presented to suggest that this has changed (see summary comment 4).

d) Where available, opposing scientific studies are acknowledged and discussed.

Conclusions

The status report appears fairly complete in its current form. The BRT cannot overstate the need for fisheries independent population assessments. The BRT should consider recognizing the Gulf and Atlantic populations as unique populations, if not subspecies at a stage of incipient speciation. Additional data on habitat threats with respect to coastal demographics/social changes and their affect on the oyster fishery would help determine if these are a legitimate threat. Overutilization, although not identified as a major threat, has been identified as the primary cause of the decline in oyster stocks on the Eastern seaboard and should continue to be evaluated. True quantitative stock assessments are necessary and the usefulness of questionnaires is doubtful. Monitoring of stock enhancement/conservation/restoration efforts is also imperative as a future need. Persistence of the Eastern oyster is not at risk now or in the foreseeable future, but additional population data are necessary to fully evaluate this conclusion.

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Materials provided for review

National Marine Fisheries Service. 2006. Status of the Eastern Oyster (*Crassostrea virginica*).

Appendix I: Statement of Work

STATEMENT OF WORK

Consulting Agreement between the University of Miami and Dr. Jason Curole

September 19, 2006

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.