NUREG–1437
Vol. 1

Generic Environmental Impact Statement for License Renewal of Nuclear Plants

Main Report

Final Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Regulatory Research

tower discharges on water quality are considered to be impacts of small significance and because the changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. Effects of cooling tower discharges on water quality are all Category 1 issues.

4.3.3 Aquatic Ecology

Cooling towers have been suggested as mitigative measures to reduce known or predicted entrainment and impingement losses (see, for example, Barnthouse and Van Winkle 1988). The relatively small volumes of makeup and blowdown water needed for closed-cycle cooling systems result in concomitantly low entrainment, impingement, and discharge effects (see Section 4.2.2 for a more complete discussion of these effects regarding once-through cooling systems). Studies of intake and discharge effects of closed-cycle cooling systems have generally judged the impacts to be insignificant (NUREG/0720; NUREG/CR-2337). None of the resource agencies consulted for this GEIS (Appendix F) expressed concerns about the impacts of closed-cycle cooling towers on aquatic resources.

However, even low rates of entrainment and impingement at a closed-cycle cooling system can be a concern when an unusually important resource is affected. Such aquatic resources would include threatened or endangered species or anadromous fish that are undergoing restoration. For example, concern about potential impacts of the Washington Nuclear Project (WNP-2) on chinook salmon has been raised by the Washington Department of Fisheries (Cynthia A. Wilson, Washington Department of Fisheries, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 5, 1990). Although entrainment, impingement, and thermal discharges are not believed to be a problem at WNP-2, the importance of the Columbia River salmon stocks are such that the resource agency feels that monitoring should continue. Similarly, the Pennsylvania Fish Commission has expressed concern about future entrainment and impingement of American shad by the Limerick Generating Station, the Susquehanna Steam Electric Station, Three Mile Island Nuclear Station, and Peach Bottom Atomic Power Station (Dennis T. Guise, Pennsylvania Fish Commission, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 3, 1990). In all cases, losses of American shad at these power plants are minimal or nonexistent, but periodic monitoring has been recommended to ensure that no future problems occur as the anadromous fish restoration efforts continue.

It is unlikely that the small volumes of water withdrawn and discharged by closed-cycle cooling systems would interfere with the future restoration of aquatic biota or their habitats. Effects of operation of closed-cycle cooling systems on aquatic organisms are considered to be of small significance if changes are localized and populations in the receiving waterbody are not reduced. In considering the effects of closed-cycle cooling systems on aquatic ecology, the staff evaluated the same issues that were evaluated for open-cycle systems (Table 4.1): impingement of fish and shellfish, entrainment of fish and shellfish early life stages, entrainment of phytoplankton and zooplankton, thermal discharge effects, cold shock, effects on movement and distribution of aquatic biota, premature emergency of aquatic insects, stimulation of nuisance organisms, losses from predation, parasitism, and disease, gas supersaturation of low dissolved oxygen in the discharge, and accumulation of contaminants in sediments or biota. Based on reviews of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, these potential effects have not been shown to cause reductions in the aquatic populations near any existing nuclear power plants. None of the regulatory and resource agencies expressed concerns about the cumulative effects on aquatic resources of closed cycle cooling system operations at this time, although some recommended continued monitoring in view of efforts to restore fish populations. Effects of all of these issues are considered to be of small significance for all plants. No change in operation of the cooling system is expected during the license renewal term, so no change in effects of cooling towers on aquatic biota is anticipated. Effects of entrainment, impingement, and discharges from closed-cycle cooling systems could be reduced by reducing the plant's generation rate, or by operating additional wastewater treatment systems. However, because the effects of cooling tower withdrawals and discharges on aquatic organisms are considered to be impacts of small significance and because the changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. The effects of closed-cycle cooling system operation on aquatic biota are all Category 1 issues.

4.3.4 Agricultural Crops and Ornamental Vegetation

The issue addressed by this section is the extent to which the productivity of agricultural crops near nuclear plants may be reduced by exposure to salts or other effects (e.g., icing, increased humidity) resulting from cooling-tower operation. The approach to evaluating this issue was as follows: first, based on a literature review, potential impacts of salts in general (whether from cooling towers or other sources such as wind-blown salts near seashores) are described according to the rate of salt deposition to earth and the relative sensitivity of different types of crops (Section 4.3.4.1); then, the data generated by monitoring programs at a representative subset of specific nuclear plants were reviewed (Section 4.3.4.2). The subset includes 10 of the 11 nuclear power plants with mechanical-draft cooling towers. Mechanical-draft towers are the focus of this section because impacts of drift deposition and icing are more likely to occur near these towers than at natural-draft towers. Drift from natural-draft towers is released at greater heights, disperses more widely, and therefore deposits on earth at lower rates or concentrations. Data were also found and reviewed for 8 of the 17 plants with natural-draft cooling towers (Table 4.1). The coal-fired Chalk Point Plant was also included in the analysis because extensive monitoring of cooling-tower-drift effects has been conducted there and because this plant uses brackish water for cooling and represents a case with comparatively high potential for drift impacts from natural-draft towers. The only nuclear plant that has a natural-draft tower and uses brackish water for cooling is Hope Creek in New Jersey. It is included among the plants that were reviewed.

The following standard of significance is applied to the effects of cooling tower operation on agricultural crops and ornamental vegetation. The impact is of small significance if under expected operational conditions measurable productivity losses (either quantity or

Appendix F

Methodology for Assessing Impacts to Aquatic Ecology and Water Resources

METHODOLOGY FOR ASSESSING IMPACTS TO AQUATIC ECOLOGY AND WATER RESOURCES

F.1 LIST OF ISSUES

The nonradiological aquatic effects of continuing operations during a license renewal period are not unique to nuclear power plants but instead are typical of potential impacts from any large steam-electric power plant (whatever the fuel type) and operation of the associated condenser cooling systems. The aquatic resources issues listed in Table F.1 have been identified from literature reviews, reviews of environmental impact statements (EISs), and professional contacts.

All of the issues listed in Table F.1 are addressed in Chapters 3 and 4, but primary emphasis is on the areas of water use, intake effects (entrainment and impingement), and thermal and chemical discharges. These areas consistently have been the most common issues raised in power plant impact assessments and permitting actions, and they have been the subject of considerable study and postoperational monitoring.

F.2 SOURCES OF INFORMATION

Information about historical and ongoing aquatic impacts associated with nuclear power plants was obtained from three general sources: (1) contacts with state and federal resource and regulatory agencies, (2) a survey of utilities that operate nuclear power plants, and (3) published literature.

Agencies with responsibility either for regulating the construction and operation of protection and maintenance of aquatic resources in the vicinity of the power plants were contacted for this document. For example, the U.S. Environmental Protection Agency (EPA) is responsible for protecting the quality of waters receiving discharges from the power plants and regulating the operation of the condenser cooling water intake and discharges. Regulation of intake and discharge effects to prevent significant impacts to aquatic communities is carried out by issuance and periodic renewal of National Pollutant Discharge Elimination System (NPDES) permits and, if necessary, by Clean Water Act Section 316(a) and (b) determinations (see Section 4.2 for a discussion of these regulatory requirements). Most often these permitting responsibilities have been delegated to the water quality regulatory agencies of the individual states. Although the state fish and wildlife agencies, the U.S. Fish and Wildlife Service (FWS), and the National Marine Fisheries Service (NMFS) do not issue permits to the nuclear power plants, they are concerned about the protection and enhancement of aquatic resources and thus have an essential consulting role with the U.S. Nuclear Regulatory Commission (NRC). Resource agency concerns may range from maintenance or enhancement of sport and commercial fisheries to protection of threatened and endangered species to restoration of anadromous fish or aquatic habitats.

Information request letters were sent to 151 individuals representing 74 state regulatory and resource agencies and to representatives in all of the regions of EPA, FWS, and NMFS. The letters solicited agency input

Table F.1 Aquatic resources issues associated with the refurbishment and op... ation of nuclear power plants

Refurbishment

- Soil erosion and sedimentation
- Water quality degradation from spilled chemicals

Operation

Water quality, hydrology, and use issues

- Water use conflicts
- Effects of consumptive water use on riparian communities
- Altered current patterns at intake and discharge structures
- Altered salinity gradients
- Temperature effects on sediment transport capacity
- Altered thermal stratification of lakes
- Scouring caused by discharged cooling water
- Eutrophication
- Discharge of chlorine or other biocides
- Discharge of other chemical contaminants (e.g., metals)
- Discharge of sanitary wastes

Aquatic ecology issues

- Threatened or endangered species
- Impingement of large organisms on the intake screens
- Entrainment of organisms into the condenser cooling water system
- Heat shock
- Cold shock
- Effects on movements and distribution of aquatic organisms
- Premature emergence of aquatic insects
- Stimulation of nuisance organisms (e.g., shipworms)
- Increased losses caused by predation, parasitism, and disease among organisms exposed to sublethal stresses
- Gas supersaturation (gas bubble disease)
- Low dissolved oxygen in the discharge
- Accumulation of contaminants (e.g., chlorinated organic materials or metals) in sediments or biota

about any existing or potential problems associated with operation of nuclear power plants in their state or region and any issues to be treated in thelicense renewal effort. An example information request letter is shown in Figure F.1. Responses were received from 17 federal agency regions and 55 state agencies, some of which provided references to specific studies that had been conducted to assess power plant impacts. These responses were used to augment information available from other sources on power plant effects.

A survey of all electric utilities that operate nuclear power plants was developed by Oak Ridge National Laboratory (ORNL) staff and administered by the Nuclear Management and Resources Council (NUMARC). The survey was intended to obtain the utilities' overview of the impacts of their power plants on aquatic resources. The survey contained nine questions related to aquatic resources; these are listed in Table F.2. As with the agency information requests, the utility responses to the survey were used as another source of information for assessment of power plant effects on aquatic resources.

For further information on aquatic impacts of power plant operations, published literature was reviewed, including peer-reviewed scientific journal articles that resulted from impacts studies, as well as periodic and topical reports submitted to or prepared by agencies [e.g., NRC EISs for the construction permit and operating license, environmental monitoring reports to the NRC, periodic reports to agencies associated with NPDES permits, and Section 316(a) and (b) demonstrations].

F.3 ANALYTICAL APPROACH

Analysis of impacts to aquatic resources focused on effects of power plant operation on water quality, water use, and aquatic biota. The potential impacts to these resources stem mainly from operation of the cooling water systems, although possible effects of refurbishment during the license renewal period were also examined.

Potential impacts to aquatic resources during the license renewal period result primarily from operation of the condenser cooling system. Water quality and availability can be altered by (1) use of biocides to prevent condenser tube fouling; (2) loss of water through evaporation, especially from cooling towers; (3) discharge of salts, metals, and other chemical contaminants; and (4) discharge of heated effluents. Aquatic biota can be affected by entrainment, impingement, and water quality changes from discharge of heated effluents and chemical contaminants. All of these effects were considered by the NRC in the EISs associated with the construction permit and operating license; they continue to be evaluated by the EPA or the state water quality permitting agency as part of the issuance and periodic renewal of the NPDES permit.

The approach used to assess effects of license renewal of existing nuclear power plants was to obtain information relating to these aquatic resources issues from monitoring data, other published information, and utility and regulatory agency contacts. If no impacts have been demonstrated for a given issue during the initial operating period of any plant, then continued operation under similar circumstances during the relicense period would not be expected to result in significant impacts. If impacts have been demonstrated

ORNL-DWG-90-16007

Date

Dear ________:

Oak Ridge National Laboratory is developing a report for the U.S. Nuclear Regulatory Commission that will evaluate environmental impacts of relicensing of nuclear power plants. Information on 118 reactors at 74 sites in the U.S. is being gathered to evaluate potential impacts from relicensing and an additional 20 or more year relicense period (beginning 40 years after the original license).

The results of this study will be used to modify 10 CFR 51 "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions." These modifications may result in some issues no longer being considered for nuclear plants in National Environmental Protection Agency evaluations at their time of relicensing. Therefore, it is important that we obtain information from your office to help in evaluating any impacts of nuclear plants in your state with regard to fish and wildlife resources.

We would appreciate any information you may have on existing impacts and on the presence of important fish and wildlife resources that may be affected by continued operation of the _______ Nuclear Plant(s) and their power lines. For your convenience, a list of such resources and potential impacts is attached.

We would like to have your response by June 30, so that we can use the information in preparing the draft report. Thank you for your assistance.

Sincerely,

Glenn F. Cada
Aquatic Ecologist
Bldg. 1505, MS-6036
Phone: 615/574-7320

Roger L. Kroodsma
Terrestrial Ecologist
Bldg. 1505, MS-6038
Phone: 615/574-7310

Figure F.1 **Example information request letter sent to state fish and wildlife resource agencies, state water pollution control agencies, and regions of the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Environmental Protection Agency.**

List of Important Fish and Wildlife Resources
and Potential or Known Impacts

- Important sport and commercial fisheries and level of harvest
- Important spawning, nursery, or other habitats for aquatic fauna
- Impacts of entrainment, impingement, or thermal and chemical releases on aquatic biota
- Adverse effects of water withdrawals or discharges on water quality and water use
- Other sources of impacts (e.g., other power plants, industrial discharges, agricultural runoff) that could contribute to cumulative impacts to aquatic resources
- Construction impacts (construction for relicensing is expected to be relatively minor and entirely contained within existing site boundaries)
- Aquatic or terrestrial flora and fauna that are listed as threatened or endangered
- Salt drift and icing impacts on vegetation as a result of cooling towers or cooling ponds
- Bird mortality due to collision with power lines and natural draft cooling towers
- Impacts on fauna as a result of vegetation cutting and herbicides in power line corridors
- Rare plant communities
- Bird colonies
- Bird roosts (e.g., raptors)
- Waterfowl staging areas
- Wetlands
- Breeding/strutting/wintering grounds for big game or certain gallinaceous birds

Figure F.1 **Example information request letter sent to state fish and wildlife resource agencies, state water pollution control agencies, and regions of the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Environmental Protection Agency.** (continued)

Table F.2 Questions relating to nuclear power plant impacts on aquatic resources that were part of the electric utility survey

1. Post-licensing modifications or changes in operations of intake or discharge systems may have altered the effects of the power plant on aquatic resources or may have been made specifically to mitigate impacts not anticipated in the design of the plant. Describe any such modifications or operational changes to the condenser cooling water intake and discharge systems since the issuance of the operating license

2. Summarize and describe (or provide documentation of) any known impacts to aquatic resources (e.g., fish kills, violations of discharge permit conditions) or National Pollutant Discharge Elimination System (NPDES) enforcement actions that have occurred since issuance of the operating license. How have these been resolved or changed over time? The response to this item should indicate whether impacts are ongoing or were the result of start-up problems that were subsequently resolved

3. Changes to the NPDES permit during operation of the plant could indicate whether water quality parameters were determined to have no significant impacts (and were dropped from monitoring requirements) or were subsequently raised as a water quality issue. Provide a brief summary of changes (and when they occurred) to the NPDES permit for the plant since issuance of the operating license

4. An examination of time trends in the results of aquatic resources monitoring can indicate whether impacts have increased, decreased, or remained relatively stable during operation. Describe and summarize (or provide documentation of) results of monitoring of water quality and aquatic biota (e.g., related to NPDES permits, environmental technical specifications, site-specific monitoring required by federal or state agencies). What trends are apparent over time?

5. Summarize types and numbers (or provide documentation) of organisms entrained and impinged by the condenser cooling water system since issuance of the operating license. Describe any seasonal patterns associated with entrainment and impingement. How have entrainment and impingement changed over time?

6. Aquatic habitat enhancement or restoration efforts (e.g., anadromous fish runs) during operation may have enhanced the biological communities in the vicinity of the plant and increased its impacts beyond that originally anticipated. Alternatively, degradation of habitat or water quality may have resulted in loss of biological resources near the site. Describe any changes to aquatic habitats (both enhancement and degradation) in the vicinity of the power plant since the issuance of the operating license that may have resulted in different plant impacts from those initially predicted

Table F.2 (continued)

7. Plant operations may have had positive, negative, or no impacts on the use of aquatic resources by others. Harvest by commercial or recreational fishermen may be constrained by plant operation or may be relatively large compared with fish losses caused by the plant. Describe (or provide documentation for) other nearby uses of waters affected by cooling water systems (e.g., swimming, boating, annual harvest by commercial and recreational fisheries) and how these have changed since issuance of the operating license

8. Describe other sources of impacts to aquatic resources (e.g., industrial discharges, other power plants, agricultural runoff) that could contribute to cumulative impacts. What are the relative contributions by percentage of these sources, including the contributions due to the power plant, to overall water quality degradation and losses of aquatic biota?

9. Provide a copy of your Section 316(a) and (b) Demonstration Report required by the Clean Water Act. What 316(a) and (b) determinations have been made by the regulatory authorities?

at some plants, then the analysis attempted to define the source and extent of the problem, to examine efforts to mitigate the problem, and to determine whether these site-specific impacts represent potential issues for the entire industry. The conclusions of this analysis were used to make judgments about limiting or eliminating the treatment of particular issuesin the license renewal applications of particular types of plants.

Because this Generic Environmental Impact Statement (GEIS) is intended to consider potential impacts across the industry and is not a site-specific license renewal action, the corresponding information required for the analysis is different. The objective is not to evaluate in detail the effects of each nuclear power plant on aquatic ecosystems but rather to examine information available from a variety of sources from a large sampling of plants with a view toward defining common, industry-wide issues that may need to be addressed in (or can be eliminated from) future license renewal actions. The assessments of aquatic resources issues in this GEIS are necessarily less detailed than the full analyses typically performed at the initial licensing stage. In such full analyses, the applicant supplied an environmental report containing detailed results of sampling programs, with appropriate analyses. The NRC staff reviewed this material, usually obtaining clarification and further information, and visited the site and discussed the information in detail as part of their independent analyses of the costs and benefits of the proposed action.

The possible endpoints of the evaluation of aquatic ecological effects in this GEIS are also constrained, regardless of the amount of information available from operation during the initial license period. Power plant impacts cannot be measured simply by comparing preoperational data with postoperational data. To accurately evaluate the impact of a power plant, one needs to know what the environment would have been like if the power plant had not been built (NUREG-CONF-002). This is not generally possible for aquatic systems. Reservoirs change as they age (in productivity and potentially in species composition). Even in rivers or estuaries, standing crops of fish change from year to year, or even from decade to decade. These systems' responses to changes in environmental, biological, and anthropogenic factors are poorly understood. Power plants superimpose their effects on a mosaic of background influences from water flow rates, temporal pattern of runoff, temperature, productivity of other trophic levels, competition and predation, chemical pollution, habitat modification, fishing pressure, and other factors. However, the acceptability of power plant effects must be periodically reconsidered in the renewal of NPDES permits. The judgment that a facility employs "best available technology" or ensures a "balanced, indigenous population of shellfish, fish and wildlife" connotes that such effects, although real, are acceptable.

Because the nuclear power plants considered in this GEIS are now operating, some kinds of local (near-field, short-term) impacts (e.g., on benthic organisms) can be measured from localized studies at the intake and discharge. Mainly of interest, however, are the system-level (ultimate, long-term, population-level) effects, particularly on fish and shellfish. Models and professional judgment have been used to extrapolate the local power plant impacts to the resulting long-term, far-field effects on the whole system (Section F.4). Comparisons can also be made with sites not directly affected. Because of the interfering effect of other factors, however, such comparisons do not represent the actual system-level effects attributable solely to a power plant.

It is possible to measure the behavior of aquatic systems affected by operating nuclear power plants through time. Usually, a limited amount of data is collected before power plant operation. If the effects of the plant were drastic enough, an obvious change coinciding with operation could be detected when preoperational data were compared with postoperational data. Combined with information about near-field plant impacts, the change could be attributed to the plant. With less drastic plant impact, monitoring might show maintenance of a balanced and indigenous aquatic community. This does not always mean that the plant is without impact but could indicate that we are unable to detect a change from preoperational conditions (whether in spite of, because of, or regardless of the effects of the plant). However, it is reasonable to conclude that system-level effects are not evident, and whatever effects the plant is having are acceptable.

When the amount of preoperational data available is small, our confidence that the plant's impact is not serious is greatly reduced (Van Winkle et al. 1981). Uncertainties also arise when changes in the system occur that may be caused primarily by natural or anthropogenic factors (e.g., fish restoration projects or changes in fishing regulations).

The main purpose of our assessments is to identify aquatic ecology issues that generally do not need to be considered in the license renewal process as opposed to those that may or do need to be considered. By examining evidence for system-level effects (e.g., from entrainment and impingement) based largely on operational information, we can determine whether there is clear evidence for effects or whether the importance of these effects is still uncertain and may need to be resolved before license renewal. In this latter case, we cannot dismiss the issue for all plants, but its potential importance for many plants would be greatly lessened.

F.4 PLANT-SPECIFIC ANALYSIS

In addition to the review of all aquatic resources issues, selected issues were examined in greater detail for a subset of power plants. These issues, entrainment and impingement of fish and the effects of thermal discharges on aquatic biota, were the most common concerns expressed by the agencies. Because of factors such as large cooling water withdrawal and discharge rates, high Δ-Ts (large increases in temperature between intake and discharge) (Table 2.3), unique characteristics of the water body, or concerns expressed by the resources agencies, the power plants selected for detailed evaluation are believed to represent the types of power plants with the greatest potential for intake and discharge effects. These examples also represent a variety of aquatic systems affected by nuclear power plant operations, including reservoirs [Arkansas Nuclear One (ANO) and William B. McGuire Nuclear Station], the Great Lakes (D. C. Cook Nuclear Power Plant and the cumulative effects of Lake Michigan nuclear power plants), large rivers (cumulative effects of Hudson River power plants), and marine systems [San Onofre Nuclear Generating Station (SONGS) and the Crystal River Nuclear Plant]. Although some power plants with once-through cooling systems operate in relative isolation from other obvious sources of man-induced stress to aquatic biota, most of the examples considered here may affect aquatic resources in conjunction with other nuclear and coal-fired power plants, and therefore may represent the most severe cases. Where appropriate, the cumulative effects of these combined sources of stress have also been discussed.

F.4.1 Arkansas Nuclear One

The ANO station is a 2-unit, 1762-MW(e) plant located in Pope County, Arkansas, on Lake Dardanelle, an impoundment of the Arkansas River completed in the 1960s. Unit 1 uses a once-through cooling system, whereas Unit 2 has a natural-draft cooling tower system. Intake water is withdrawn from the Illinois Bayou arm of Lake Dardanelle through a 981-m (3220-ft) canal. The discharge is through a 158-m (520-ft) canal to an embayment of Lake Dardanelle. The Δ-T at full load is 8.3°C (15°F) for Unit 1. Because of the small volumes of blowdown associated with the closed-cycle cooling system of Unit 2, its contribution to discharge temperature increases is negligible. Arkansas Power and Light (AP&L) has conducted an extensive environmental monitoring program relating to the effects of ANO on Lake Dardanelle, including the effects of heated water discharges, impingement, and entrainment.

ANO has operated under a series of NPDES permits issued by EPA; no Section 316(a) demonstration has been required. Utility consultations with EPA Region 6 in the early 1980s confirmed that there was no 316(b) requirement; reevaluation would be needed only if there were a dramatic change in impact [AP&L, response to NUMARC survey (NUMARC)]. The following sections discuss the impacts of ANO operation.

F.4.1.1 Thermal Discharges

A portion of AP&L's monitoring program is designed to assess the impacts of the thermal discharge on fish and aquatic life (AP&L 1984). Discharge temperature is limited to 35°C (95°F), with a maximum increase over ambient of 2.8°C (5°F) based on a monthly average of daily depth-averaged values measured at unspecified locations in Lake Dardanelle (Geo-Marine, Inc. 1976; AP&L 1984). Most of the heat added to the water is dissipated within 2.5 km (1.6 miles) of the point of discharge (Rickett 1983).

The plant discharge has been studied with respect to effects on physicochemical parameters, phytoplankton, zooplankton, and fish. Statistically significant differences in turbidity, suspended solids, chloride, and hardness, but not conductivity, were found between the intake area and an upstream area in Lake Dardanelle, but not between the intake and the discharge (Rickett and Watson 1985). The differences appear to be small and may be the result of characteristically different water quality in the Illinois Bayou and the Arkansas River mainstream (e.g., Geo-Marine, Inc. 1976). A comparison of the phytoplankton communities at close versus distant sampling stations after power plant operation began showed (1) no noticeable effects on phytoplankton abundance and the number of taxa and (2) no significant effects on diversity (Rickett and Watson 1983b), although an indication is given that phytoplankton were stimulated at close stations (Rickett and Watson 1983a). The heated effluent was considered to have slightly suppressed overall abundance and variety, but not diversity, of the zooplankton community, and to have generally increased the ratio of phytoplankton to zooplankton abundance at close stations (Rickett and Watson 1983a). Also attributed to the power plant was a dominance exchange between the rotifer genera *Brachionus* and *Polyarthra*, with the latter genus moving from third to first rank in terms of the number of times it was dominant at individual sampling stations (both close and distant). Such a shift is consistent with experimental results showing an increase in abundance of *Polyarthra major* in a heated enclosure relative to an unheated control (CONF-740820).

Evaluating effects of the discharge on fish communities is one of the main objectives of multiyear fish surveys conducted by AP&L. Fish are attracted to the discharge area in the winter and to the intake area in the summer; sport fish tend to avoid the discharge area in the summer because of the elevated temperatures [AP&L, response to NUMARC survey (NUMARC)]. Concern was expressed in the Final Environmental Statement (FES) for Unit 1 (AEC Docket 50-313) about potential cold shock in the event of rapid plant shutdown during the winter. Recent information [AP&L, response to NUMARC survey (NUMARC 1990)] does not discuss whether such shutdowns have occurred, but only one significant fish kill incident (excluding entrainment and impingement mortality) is reported from 1974 through 1989. The deaths, in the discharge area, were related to lordosis (humpback or crooked spine). This abnormality may have been caused primarily by toxaphene, an agricultural pesticide that washed into the reservoir from the surrounding watershed and was enhanced by the thermal discharge. Toxaphene was banned, and lordosis has rarely been observed after 1978 [AP&L, response to NUMARC survey (NUMARC 1990)].

Time trends in mean weights of adult fish have been examined over several years (Tilley 1983). Mean weights for five species of fish tended to be somewhat higher in the discharge embayment than in stations elsewhere, as did the ratio of predators to prey based on weights. It was concluded that species composition in the reservoir had not reached equilibrium in the 15 years after impoundment, and it was considered unlikely to do so in the future. The species composition in the vicinity of the discharge is, however, not significantly different from that in other sample areas (Tilley 1983).

F.4.1.2 Entrainment and Impingement

The potential for entrainment at ANO is not negligible. At full power operation, the plant withdraws 48 m^3/s (765,000 gal/min) of water. If the reservoir is viewed as a closed system, this is 0.5 percent of the reservoir volume per day. Viewing the reservoir as an open system, the intake is 5 percent of the mean flow through the reservoir; much larger percentages can be calculated during periods of low flow. Although these percentages do not represent estimates of entrainment or impingement, they may be large enough to result in significant impacts.

An assessment of entrainment at ANO has been conducted by AP&L (1990). Summary data are presented for 1977–1982 for fish larvae from meter net samples in the Illinois Bayou in the vicinity of the entrance to the intake canal and in the intake canal itself. Clupeid larvae represented 79–97 percent of all larvae captured in the entrainment samples, depending on the year. Although clupeids were the most frequently entrained larvae, these species have been able to reestablish themselves in the intake area and the reservoir each year. AP&L does not regard entrainment at ANO as having a significant impact on these or other species of fish in the lake (AP&L 1990).

Impingement samples have been taken from at least 1974 through 1982. Impingement has been substantial. In the FES for Unit 2, NRC staff reported that from June 10, 1974, through July 19, 1975, 34 species had been impinged at Unit 1; estimated impingement was 27.5 million fish weighing 213,000 kg (470,000 lb), of which 99.6 percent by number and 99.3 percent by weight were threadfin or gizzard shad (NUREG-0254). These fish were predominantly young-of-year and presumably stressed by low water temperatures (Zweiacker et al. 1977). Ten million fish weighing 97,900 kg (215,900 lb) were impinged during the first year of operation, compared with an average impingement of 2 million fish weighing 13,000 to 30,000 kg (29,000 to 66,000 lb) in ensuing years [AP&L, response to NUMARC survey (NUMARC 1990)]. Also during 1974–1975, an air bubble curtain was evaluated as a possible means of reducing impingement. It was considered ineffective. Impingement levels were found to be inversely correlated with temperature (Zweiacker et al. 1977).

An indication of the magnitude of ongoing impingement can be obtained by comparing estimated impingement of fish with estimated reservoir standing crops. These estimates were provided for 1981 for some of the more important commercial and sport fish and forage fish in the reservoir. Impingement in 1981 represented less than 3 percent of the estimated gizzard shad population and less than 13 percent of the estimated threadfin shad population, either by numbers or by weight. For the 11 other species, the fraction was 1 percent or less and usually less than 0.1 percent. Impingement rates of the magnitude estimated for threadfin shad could have a significant effect on the population, although demonstrating (i.e., measuring) the effect would probably be impossible given the limited preoperational data and the natural variability inherent in fish populations (Van Winkle et al. 1981). Loar et al. (1978) studied impingement of threadfin shad at 32 southeastern power plants, including ANO. The impingement rate of shad [number impinged per million cubic meters (2.6×10^8 gal) of water withdrawn] at ANO was more than 4 times that of the second highest plant in their study and more than 10 times higher than rates at the other nuclear power plants. Loar et al. concluded that the characteristic of peak winter impingement of threadfin shad was widespread for southeastern U.S. power plants between 33° and 37° N latitude (ANO is near 35° N latitude) and that impingement rates were higher in reservoirs than on rivers. They could not firmly relate the rates to type of intake structure or to plant operational parameters (e.g., flow rates; velocity near the intake screens).

F.4.1.3 Summary of Impacts

Information about preoperational (1969–72) and postoperational (1975–84, except for 1979) standing crops of fish from Lake Dardanelle are available in one of the National Reservoir Research Data Bases. Four multivariate analyses of variance, or MANOVAs, of the Lake Dardanelle data were conducted. These compared preoperational status of fish communities in the reservoir with postoperational status based on standing crops for selected important commercial, sport, or forage species within four groups of fish: clupeids (threadfin shad, gizzard shad, and skipjack herring); catfishes (channel catfish, flathead catfish, and blue catfish); basses (largemouth bass, striped bass, and white bass); and crappies and sunfishes (black crappie, white crappie, bluegill, and longear sunfish). A significant ($p < 0.05$) difference was found only with the basses. The individual univariate analyses of variance, or ANOVAs, for individual bass species showed a significant decrease in largemouth bass. However, a nonparametric test using the Mann-Whitney U statistic showed, in addition, a significant increase in striped bass (which had not been caught at all in the preoperational period). Whether these changes are related primarily to operation of ANO, to natural changes in Dardanelle Reservoir as it ages, or to other anthropogenic factors is not clear. Because entrainment and impingement of largemouth bass are low, substantial effects of ANO on this species would only be expected as an indirect consequence of effects on one of their food sources, clupeids; such effects on clupeids were not detected.

The combined effects of thermal discharges and entrainment and impingement stresses are likely greatest on the threadfin and gizzard shad populations. Quantifying the level of stress would require extensive additional analyses, far beyond the scope of this GEIS. Evaluating the consequences of these effects and stresses at the fish population level presents additional difficulties, due in large part to uncertainty about biological compensatory mechanisms (EPRI EA-5200s). However, as AP&L points out, threadfin and gizzard shad are able to reestablish themselves in the intake area and the reservoir each year [AP&L, response to NUMARC survey (NUMARC 1990)]. Effects of changes in zooplankton dominance and high annual levels of shad impingement are not apparent. In addition, state and federal regulatory agencies have not expressed concern about operation of ANO.

F.4.2 William B. McGuire Nuclear Station

The William B. McGuire Nuclear Station is a 2-unit, 2360-MW(e) plant located on Lake Norman, the largest impoundment in North Carolina. Both units use a once-through cooling system, drawing a combination of surface water from a manmade embayment and deep water from an intake located near the base of Cowan's Ford Dam. The near-shore discharge is channeled through a canal 1 km (0.6 mile) long. The Δ-T (change in temperature) at full load ranges from 8.6° C

(15.5°F) in the summer to 13.7°C (24.7°F) in the winter (Duke Power Company 1985).

Concerns about McGuire's impacts to aquatic resources have focused mainly on effects of heated water discharges on recreational fisheries (DUKE PWR/82-02), although entrainment and impingement are also of potential concern for aquatic life. Water use has also been identified as an issue.

Lake Norman was impounded in 1963 primarily for power generation. The Marshall Steam Station (coal-fired) also uses the lake for cooling water; with both facilities operating, the lake has the highest thermal loading from the discharge of once-through condenser cooling water of any lake of comparable size in the United States (DUKE PWR/82-02). Several sport fish species have been successfully introduced to the reservoir. Largemouth bass, crappie, striped bass, and white bass dominated the fishery in the early 1980s (DUKE PWR/82-02).

The following sections discuss the major potential sources of impacts from the McGuire plant.

F.4.2.1 Thermal Discharges

Extensive attention has been devoted to evaluating the thermal effects on Lake Norman of discharges from both Marshall and McGuire. Postoperational versus preoperational comparisons of fish standing crops based on cove rotenone sampling show fluctuations, but the only documented trend is a decline in gizzard shad standing stocks near the discharge since operation [Duke Power Company, response to NUMARC survey (NUMARC 1990)]. Minor sporadic die-offs of striped bass and yellow perch have been observed before and after operation of McGuire. These have been attributed to a loss of oxygenated cool-water habitat. The original NPDES permit for McGuire specified a maximum discharge temperature of 35°C (95°F). A new permit, issued in 1990, increases this limit to 37°C (99°F) during July to September. The new higher limit can be attained with a lower proportion of cool, deep (hypolimnetic) water from the lower-level intake structure. This in turn is expected to reduce the depletion of habitat for cool-water fish species (primarily adult striped bass and yellow perch).

Avoidance of the discharge area by fish during summer, which varies depending on the level of operation, has been documented and will probably increase with the new thermal limit. Because areas of Lake Norman water affected by thermal discharges will be increased only by approximately 1 percent as a result of the changed limits (Duke Power Company 1988), the loss of summer aquatic habitat should have negligible effects on fish populations. Attraction of fish to the discharge area during cooler months has occurred in the past and will probably continue. The likelihood of mortalities due to cold shock is substantially reduced with two units operating. No incidences have been reported of fish mortalities resulting from thermal shock in the first few years of operation (Carter 1990).

Gas bubble disease (GBD), which sometimes leads to mortality, has regularly been observed in the discharge of the Marshall plant (McInerny 1990). Duke Power (1985) projected only low incidences of GBD for the McGuire station, based on operating data from Marshall and the Δ-Ts expected for McGuire. In the limited postoperational data provided, the incidence of GBD was low. Incidence of disease and parasitism was also low, both in preoperational and operational years (Duke Power Company 1985).

F.4.2.2 Entrainment and Impingement

The only report currently available about entrainment and impingement is from a preoperational, predictive study (Duke Power Company 1978). Threadfin shad were expected to be the fish species most subject to both entrainment and impingement. A formal 316(b) demonstration has not been required at McGuire, and no extensive studies of fish entrainment and impingement have been conducted (Carter 1990).

F.4.2.3 Cumulative Impacts

Combined effects of the Marshall and McGuire plants on fisheries are difficult to document. This difficulty is typical of situations where not only power plants but also other external factors are operating on the system. Despite the potential for entrainment, impingement, and thermal effects, the overall fish populations of Lake Norman appear to be healthy and to support an increasing amount of recreational activity. In responses from federal and state agencies, the North Carolina Wildlife Resources Commission expressed a concern about mortalities of large striped bass in Lake Norman but also indicated that it was uncertain whether these are related to operation of McGuire (Hamilton 1990).

Consideration of impacts to aquatic resources in Lake Norman is an ongoing cooperative effort between Duke Power Company and the resource and regulatory agencies (Lewis 1990). This is evidenced by the recent modification of maximum discharge temperatures of the McGuire station to protect cool-water fish habitat.

F.4.3 D. C. Cook Nuclear Power Plant

The D. C. Cook Nuclear Power Plant is a 2-unit, 2130-MW(e) plant located on the southeastern shore of Lake Michigan. The plant uses a once-through cooling system for both units, drawing water from three intake cribs located 680 m (2231 ft) offshore in 7.3 m (24 ft) of water (Thurber and Jude 1984). Cooling water is also discharged offshore through two slot-jet discharge structures located 366 m (1200 ft) offshore in 5.5 m (18 ft) of water. The maximum temperature to which discharged water is heated above ambient temperatures (i.e., the Δ-T) is variously reported as 10°C (18°F) (Evans et al. 1977; Evans 1984; Chang and Rossman 1985) or 21°C (38°F) (Thurber and Jude 1984). A riprap bed of crushed limestone was deposited around the intake and discharge structures during construction to prevent erosion and scour.

Concerns about D. C. Cook impacts to aquatic resources have focused on effects of entrainment, impingement, and heated water discharges on recreational and commercial fisheries. The most frequently impinged and entrained fish species in Lake Michigan are alewife, yellow perch, and rainbow smelt (Jensen et al. 1982). All three species support small commercial fisheries, and yellow perch and rainbow smelt are also important to sport fishermen. In addition, there are important cold-water sport fishes (e.g., lake trout and various other stocked salmonids) that could be affected by thermal discharges.

Chang and Rossman (1985) report that the plant no longer requires biofouling control and that chlorination did not occur during their study period. The spread of the fouling organisms *Corbicula* and the zebra mussel in the Great Lakes in recent years may once again require the use of some type of biocide. In any case, D. C. Cook would be unlikely to cause biocide impacts because it discharges treated water through a diffuser (to ensure rapid mixing and dilution) into a large body of water. Chemical effluents would be rapidly diluted and are unlikely to accumulate in the system.

F.4.3.1 Thermal Discharges

The rapid mixing of heated water and discharge into a large body of cold water is unlikely to result in significant adverse impacts. Evans studied benthic communities in the vicinity of the discharge structure and found few or no differences between the thermal plume and control areas in abundances of bottom-dwelling organisms; the few differences that were detected were limited to small areas within a few hundred meters of the intake and discharge structures.

Spigarelli et al. (1983) studied movements of a cold-water sport fish, the brown trout, near the thermal plume of a Lake Michigan power plant similar to D. C. Cook [essentially the same discharge rate and Δ-T (change in temperature)]. The trout took up residence in the thermal plume instead of avoiding it, especially during the winter months when ambient temperatures are lower than those preferred by the fish. In Lake Michigan, fish can easily avoid thermal plumes, but some species (brown trout, rainbow trout, alewife, carp, and salmon) frequently occupy these gradients (Spigarelli et al. 1983).

F.4.3.2 Entrainment and Impingement

Because of the large volumes of water withdrawn for condenser cooling of the two units and the large numbers of important fishes in the vicinity, D. C. Cook has been studied for entrainment and impingement impacts. Studies before and during operation of the plant sought changes that could be attributed to operation. Few significant effects were detected from the entrainment of phytoplankton (Chang and Rossman 1985) or zooplankton (Evans et al. 1977), and even these effects were considered inconsequential or highly localized.

Madenjian et al. (1986) used two statistical procedures to assess D. C. Cook impacts. They compared catches of alewives and yellow perch before operation (1973–74) and during operation (1975–82). Both analyses disclosed no significant power plant impacts. State and federal resource agencies contacted for this document did not express concerns about the continuing operation of D. C. Cook (Madenjian et al. 1986).

F.4.4 Lake Michigan Nuclear Power Plants

Six nuclear generating stations are located on Lake Michigan. Except for the Palisades Nuclear Plant, they all use once-through cooling. Listed with the number of units, they are Big Rock Point Nuclear Plant (1), D. C. Cook Nuclear Power Plant (2), Kewaunee Nuclear Power Plant (1), Palisades Nuclear Plant (1), Point Beach Nuclear Plant (2), and Zion Nuclear Plant (2). The near-field aquatic effects of one of these, the D. C. Cook plant, have been considered separately in this section. In addition, EPA, the Illinois Environmental Protection Agency, and the Illinois Department of Conservation all specifically identified entrainment and impingement of fish at the Zion Nuclear Plant as issues of concern; and studies of potential mitigative measures have been requested. In terms of the far-field, long-term effects, it is appropriate to consider these plants as a group and to examine their cumulative impacts, considering also other sources of impact (including fossil-fuel power plants) on Lake Michigan as a whole. This approach has been taken in several publications that consider the cumulative effects of entrainment and impingement of fish.

Kelso and Milburn (1979) evaluated cumulative entrainment and impingement during 1975 or 1976 at 89 power plants using once-through cooling systems located on all five of the Great Lakes. The combined capacity of these plants was 54,118 MW(e). Consideration was also given to an additional 17 plants with once-through cooling systems not yet operational at that time but expected to be operational by 1982, with 30,705 MW(e) additional capacity. Of these, 25 existing and 3 planned plants, with 14,932 and 4,969 MW(e) capacities, respectively, were located on Lake Michigan.

Impingement information was available from 43 percent of the existing power plants. Impingement in Lake Michigan was second highest (after Lake Ontario), with a broad peak from May to July. Entrainment information was more limited, available from only 24 percent of the plants. Regression equations were developed for annual impingement and annual entrainment as functions of power plant size (apparently, with all units combined within plants); these were used to extrapolate to plants lacking adequate data. Based on these equations, annual impingement at existing Lake Michigan plants was estimated to be about 15.4 million fish; the proposed plants were projected to increase this by 755,000 fish. The corresponding estimates for entrainment of larvae were about 196 million and 10 million, respectively.

Kelso and Milburn (1979) estimated annual impingement in the Great Lakes by these power plants of approximately 100 million fish. Calculating an average weight of an impinged fish at about 75 g (2.6 oz), they estimated that the "harvest" by power plants through impingement was at least 7500 metric tons (8300 tons), or 15 percent of the total commercial landings (about 50,000 metric tons (55,000 tons), obtained from references dated 1970 and before). Because they considered their impingement figures to be low, they estimated that impingement losses were in excess of 25 percent of the total annual commercial fish harvest. Kelso and Milburn (1979) estimated an annual entrainment in the Great Lakes of about 1.2 billion larval fish, but because of inadequate information they did not try to relate these losses to the size of the commercial catch.

Scott-Wasilk et al. (1981) believed that Kelso and Milburn's (1979) comparison of the loss estimates with commercial catch data overstated the impact. They noted that 85 percent of the impingement and entrainment was of "ecologically less desirable, but very abundant species" that are increasingly dominant in the commercial catch. Alewife and smelt stocks fluctuate substantially but have shown no consistent trends in abundance in Lake Michigan, despite the entrainment and impingement and a steadily increasing commercial catch of alewives. They considered standing crops to be a more appropriate basis for comparison. Viewed this way for Lakes Michigan and Ontario and the western basin of Lake Erie, annual impingement losses (expressed variously as numbers or as weights) typically constituted less than 1 percent of total stocks. Scott-Wasilk et al. (1981) also felt that the probable effect of power plants on sport and commercial landings was negligible and that (biological) compensatory reserves for impacted stocks, although unquantified, were probably sufficient to minimize the impact of these losses.

Kelso and Milburn (1981), in their response, noted that although losses of alewife and smelt may be small in Lake Michigan, such losses might constitute a significant reduction in the forage base for trout and salmon. The concern was also expressed that discrete stocks and local populations might be depleted by clustering power plants with once-through cooling systems in areas including the southern basin of Lake Michigan.

A different approach, involving the adaptation and use of conventional fishery stock assessment models, was taken by Jensen et al. (1982) to estimate the effects of 15 power plants on Lake Michigan. All of the nuclear plants except Big Rock Point were included. Both the surplus-production and the dynamic- pool models were applied to estimate the proportions of the Lake Michigan standing stocks of alewife, yellow perch, and rainbow smelt impinged and the proportions of eggs and larvae entrained.

The impingement proportions should be reasonably comparable to those calculated by Scott-Wasilk et al. (1981) for 17 Lake Michigan power plants. Although all of the impingement estimates calculated in either paper for Lake Michigan were less than 1 percent, the estimates of Jensen et al. (1982) for alewife (0.25 percent and 0.21 percent, depending on the model used) were substantially smaller than the 0.77 percent estimated by Scott-Wasilk et al. (1981). Conversely, the Jensen et al. (1982) estimates for rainbow smelt of 0.15 percent (both models) were more than double the Scott-Wasilk et al. estimates.

Referring to the type of analysis conducted by Kelso and Milburn (1979), Jensen et al. (1982) also presented estimates of biomass impinged as a percentage of 1975 commercial catch statistics. They estimated that impingement amounted to 10 percent of the commercial catch of alewife, 3.6 percent that of yellow perch, and 3.1 percent that of rainbow smelt which, given the recent predominance of alewife in the commercial catches, compare reasonably well with Kelso and Milburn's (1979) calculation of 15 percent of total commercial landings (all species), based on older catch data.

The main advantage of the approach taken by Jensen et al. (1982) is that, rather than just ratios, the *effects* of entrainment and impingement can be estimated on standing stocks and on maximum sustainable yields. Using the full-flow scenario, but including entrainment and impingement, they estimated reductions of standing crops (biomass) of 2.86 percent for alewife, 0.28 percent for yellow perch, and 0.76 percent for rainbow smelt. Corresponding reductions in the maximum sustainable fishery yield are larger: 4 percent for alewife, 0.5 percent for yellow perch, and 1.2 percent for rainbow smelt. Using "maximum" entrainment and impingement coefficients, there is about a 10 percent decrease in biomass (species not specified). They concluded, "Although large numbers of alewife, rainbow smelt, and yellow perch are killed by entrainment and impingement, the proportions of the populations affected are relatively small. Still, the loss of fish biomass is not negligible, and entrainment and impingement impacts need to be considered in the design of new intake facilities" (Jensen et al. 1982).

The main lesson to be learned from these analyses of entrainment and impingement impacts on fisheries in Lake Michigan is that it may not be sufficient to evaluate the significance of these types of impacts one power plant at a time. The main effects of concern are not local but relate to the entire lake (or at least to entire basins). The issue is one of resource management, and the logical level for management is at the level of the resource: cumulative impacts of all plants (and other water uses) in an area or on a lake.

F.4.5 Hudson River Power Plants

Seven power stations (including two nuclear stations, Indian Point 2 and 3), with a total net rated capacity of 5798 MW(e), are located along the Hudson River estuary between river kilometers 8 and 228 (Hutchison 1988). The most extensive consideration of entrainment and impingement impacts on the aquatic environment ever undertaken centered on these facilities. During the late 1970s, the studies, analyses, and hearings involved four federal agencies, five utilities, and numerous other parties and drew on the cumulative efforts of nearly 2000 technical personnel. The results of these studies have recently been integrated and summarized as a case study (Barnthouse et al. 1988b) that is the best available evaluation of what can and what cannot be determined about these kinds of impacts.

The greatest attention focused on the population-level effects of entrainment and impingement of fish at the three largest plants: the Indian Point Nuclear Generating Station (Units 2 and 3) and the Bowline Point and Roseton fossil-fuel plants. In particular, the final EPA hearing that ended with the 1980 settlement agreement (Barnthouse et al. 1988a) focused on whether reducing entrainment and impingement effects by retrofitting closed-cycle cooling systems to the six active units at these three facilities was necessary. However, most of the later analyses included the effects of five power plants by adding Lovett and Danskammer, two smaller fossil-fuel stations. The other two plants were near each end of the estuary beyond the region for which data were available but also outside of the main spawning and nursery areas of key fish species. Therefore, analyses assessed the cumulative impact of steam-electric power generation on the Hudson River estuary. Impacts on striped bass received greatest attention, but white perch, Atlantic tomcod, American shad, alewife, blueback herring, and bay anchovy were also considered.

Numerous mathematical models have been developed to evaluate the extent and effects of entrainment and impingement (Christensen and Englert 1988; Barnthouse and Van Winkle 1988). The Hudson River approaches differ from those used for Lake Michigan, in which the numbers entrained or impinged were related to numbers or weights of fish in the lake or caught in the fishery. Interpreting such comparisons is very difficult because (1) the entrained (and probably also impinged) fish are younger and less valuable than those in the fishable stock and (2) impingement needs to be considered in relation to the life-cycle of the fish, not just on an annual basis. In the Hudson River, these issues were moot because estimates of the absolute size of stock standing crops or fishery yields were not available, in part because of the open nature of the estuary. Rather, emphasis was placed on the conditional entrainment and impingement mortality rates (Ricker 1975) (the fraction of an initial population that would be killed during the year if no other sources of mortality operated) imposed on each year class and on the resulting projected percentage reduction of the standing stock.

A reasonable consensus was eventually achieved about the magnitude of entrainment impact (Englert and Boreman 1988; Barnthouse et al. 1988a). Estimates of conditional entrainment mortality based on historical and projected once-through cooling operations at the five power plants ranged from 5 to 7 percent for Atlantic tomcod to 35 to 79 percent for bay anchovy (Englert and Boreman 1988). For most species, the impact of entrainment was considered more important than that for impingement. For white perch, however, the estimates of conditional impingement mortality were relatively large, ranging from 10 to 59 percent (Barnthouse and Van Winkle 1988).

The Hudson River studies were relatively unsuccessful in meeting the broader objective of extending these direct impact estimates to determine the percentage reduction of the corresponding fish populations in the estuary (Klauda et al. 1988; Barnthouse et al. 1988c). Out-of-court negotiations among many of the parties involved began in August of 1979 (Barnthouse et al. 1988a) in an effort to end the stalemate that was increasingly apparent, especially concerning the long-term effects of the conditional mortality rates attributable to the power plants. These conditional entrainment and impingement mortality rates became the measures used to assess the impacts of existing operation. The successful result of these negotiations is summarized in Barnthouse et al. (1988a p. 269): "On December 19, 1980, the historic settlement agreement was signed by all parties. For the 10-year duration of the settlement, no cooling towers would be required. As an alternative, the utilities agreed to a variety of technical and operational changes intended to reduce entrainment and impingement. In addition, they agreed to supplement the production of striped bass in the Hudson River by means of a hatchery, to conduct a biological monitoring program, and to fund an independent research foundation for study of Hudson River environmental problems." The remainder of Barnthouse et al. (1988a) provides details of these elements of the settlement agreement.

The settlement agreement is expiring, and it is not certain what administrative procedures will occur in its aftermath. In responses to requests to federal and state agencies, NMFS mentioned that the Indian Point plant is "famous for entraining striped bass eggs and larvae" (Gorski 1990). The NMFS indicated that the attempt at mitigation by means of a striped bass hatchery has never been acceptable to the resource agencies, who have asked for closed-cycle cooling. The New York State Department of Environmental Conservation (NYSDEC) is the agency responsible for NPDES permits. It has expressed concerns about entrainment, impingement, and thermal discharge effects at Indian Point (Wich 1990). At present, entrainment and impingement effects at Indian Point are active issues; whether they will still be issues at the time of license renewal will be determined by the course of events that cannot now be predicted.

F.4.6 San Onofre Nuclear Generating Station

SONGS is a three-unit nuclear facility located on the coast of Southern California, roughly midway between Los Angeles and San Diego. All three units use once-through cooling systems, withdrawing water from the Pacific Ocean through submerged velocity-capped intake structures located at distances between approximately 900 and 980 m (3000 and 3200 ft) from shore in about 9 m (30 ft) of water. During normal operation, Unit 1 [436 MW(e)] withdraws water at a rate of 22 m^3/s (350,000 gal/min) and increases its temperature about 10°C (18°F) during passage through the plant. Units 2 and 3 are each rated at 1070

MW(e), and each withdraws approximately 50 m^3/s (800,000 gal/min), with a temperature increase of about 11°C (20°F). The Unit 1 discharge is through a single vertical pipe in 7.6 m (25 ft) of water about 762 m (2500 ft) from shore. Discharge of the larger units (2 and 3) is through 760-m (2500-ft) diffusers offset from one another and positioned more or less in sequence; for Units 2 and 3, they terminate 2500 m (8200 ft) and 1800 m (5900 ft) offshore, respectively.

Extensive studies of the effects of SONGS on aquatic biota have been conducted by the Marine Review Committee (MRC), appointed by the California Coastal Commission, over the period 1975–1989. These studies have recently been summarized and interpreted in a report of the MRC (MRC Document 89-02) supported by many other technical reports, databases, and other reports. Most of the conclusions are based on both near-field and far-field sampling before and after startup of Units 2 and 3. In the summary report, the extent of biological effects is estimated quantitatively. Adverse impacts are estimated to the kelp community (kelp, some fish, and kelp-bed invertebrates), to local populations of midwater fish species, and to far-field populations of fish in the Southern California Bight (the area between Point Conception and Cabo Colnett in northern Baja California). Besides quantifying these adverse impacts and identifying other biological effects, the report considers several distinct mitigative techniques, a combination of which is considered capable of providing complete mitigation (MRC Document 89-02). Note that the three-member MRC was not always unanimous in its judgments. In particular, one member felt that some of the conclusions understated the severity or extent of plant impact and that cooling towers should be installed as a mitigative measure.

Local adverse effects were measured on the kelp community in the San Onofre kelp bed (SOK), including giant kelp, kelp-bed fish, and large benthic kelp-bed invertebrates. The best estimate of reduction in the area covered by moderate- to high-density kelp in the SOK is 80 ha (200 acres). Fish living near the bottom in the SOK (e.g., sheephead, barred sandbass, and black surfperch) were estimated to be reduced by 70 percent [roughly 200,000 fish weighing about 25.4 metric tons (28 tons)] below the abundance expected in the absence of SONGS. The abundance of 13 species of snails and of the white sea urchin was estimated to have been reduced substantially (30–90 percent) below the levels expected without SONGS; other kelp-bed invertebrate species too rare to permit accurate sampling were also thought to have declined. According to the report, "these effects, although local, are deemed substantial because kelp is a valuable and limited habitat." These kelp-bed effects were attributed mainly to changes in the physical environment in the SOK as a result of the sometimes turbid discharge plume. These key environmental changes were (1) reduction in light levels reaching the bottom, (2) increases in the flow and the rates of particles near the bottom, and (3) modification of currents near the plant.

Two kinds of additional adverse impacts were attributed mainly to losses because of entrainment or impingement (see also Helvey 1985). First, reductions in the local abundance of some midwater fish populations were measured. The local abundance of queenfish (a forage fish) was reduced by an estimated 30 to 70 percent, depending on the location, out to a distance of 1.9 to 3.1 km (1.2 to 1.9 miles) from

SONGS. The estimated reduction for white croaker (a sport fish) was similar in magnitude, but over a smaller area. Several other species were believed to have experienced smaller reductions. Loss in the intake, predominantly due to impingement, was considered capable of explaining the loss of croaker and some of the loss of queenfish, but the operation of some other factor (such as plume turbidity) would also be required to explain some of the effects.

The second adverse entrainment/impingement impact concerns far-field effects. Consistent with the evaluation of such far-field effects in other plant-specific analyses (see, for example, the Hudson River power plants), the MRC report also recognizes that "even a major effect will be so diluted that the change will be indistinguishable from natural variation." For these effects, the MRC relied on inferred reductions rather than on attempts to measure effects. An "equivalent adult losses" method was used to estimate losses in recruitment due to measured (interpolated for young juveniles too small to be impinged) entrainment and impingement, and assumptions were made about the effect of biological compensation. Reductions "probably between one and ten percent" in the standing stocks of several midwater fish populations in the Southern California Bight were inferred. Because these latter entrainment/impingement effects could occur over large populations, they were considered by MRC to be substantial.

In contrast to these particular groups of organisms for which adverse plant impacts were measured or inferred, other groups of organisms showed no change or increased locally in abundance. With the exception of meroplankton (benthic larvae), which increased, other plankton was largely unaffected by operation of SONGS. Also, although entrainment of fish larvae, which are concentrated inshore at about the depths of the intakes, is considered an important contributor to reductions in adult stocks, there is no clear pattern of decreases in the abundance of fish larvae near SONGS. Differences between local and more distant sand crab populations are also felt to be unrelated to plant operation. General patterns of increases were seen among local benthic fish populations, soft-bodied benthic invertebrates, and mysids (semi- planktonic shrimp-like crustaceans).

Besides quantifying the biological effects of the operation of SONGS, the MRC report made recommendations concerning two sets of potential mitigative options. The first set concerned structural changes to the power plant. A majority of the MRC was opposed to backfitting cooling towers, and the MRC also discouraged moving the discharge diffusers. The second set of options would involve implementation of three to five mitigative techniques, selected from more than 30 that were considered. Finally, the MRC recommended increased monitoring as part of the changes to the NPDES program to determine the value of mitigative measures.

F.4.6.1 Cumulative Impacts

The MRC report (MRC Document 89-02) does not explicitly consider SONGS in the context of other power plants, of which there are at least six in the Southern California Bight (Helvey 1985). However, the fact that entrainment and impingement at these plants also contributes to impacts is recognized, and reduction of these impacts at other nearby plants is an optional part of one mitigative measure recommended by the MRC. In fact, noting studies at SONGS indicating that the thermal effluent from the plant is of little environmental concern, the

MRC states that "the greatest environmental protection might result from a waiver of thermal standards at Southern California Electric's coastal power plants, because this would minimize the volume of water pumped through the plants" (MRC Document 89-02, pp. 297–298).

As of late 1990, the California Coastal Commission had not acted on the MRC's recommendations (personal communication, R. F. Ambrose, Marine Science Institute, University of California, Santa Barbara, to S. W. Christensen, ORNL, Oak Ridge, Tennessee, October 5, 1990). The final MRC report initially gives the impression of considerable confidence in the conclusions of impact and in the ability of the recommended mitigative measures to achieve complete mitigation. Further reading reveals the importance of many estimates and assumptions made in reaching the conclusions and an explicit discussion of uncertainties. Whether the report's conclusions are contested or not remains to be seen. Nonetheless, the report demonstrates the ability of a focused, long-term project, applying consistent sampling and study techniques, to reach meaningful conclusions about the impacts of a power plant on aquatic organisms and about ways to mitigate these impacts.

F.4.7 Crystal River Nuclear Plant

The Crystal River Power Station consists of five units that withdraw cooling water from the Gulf of Mexico. Only one of the units, Unit 3, is nuclear powered; the other units are coal-fired. Two of the coal-fired units use closed-cycle cooling; the remaining units are once-through. All units use a common 5.5-km- (3.4-mile-) long intake canal and a 2.6-km- (1.6-mile-) long discharge canal (FPC 1985). Unit 3 discharges heated water into Crystal Bay at a rate of 43 m^3/s (680,000 gal/min) (Table 2.1); the total discharge of the three once-through units is approximately 83 m^3/s (1,318,000 gal/min) (FPC 1985). The change in temperature of the Unit 3 condensers is 9.5°C (17.1°F) (Table 2.3).

Important aquatic resources of Crystal Bay include a diverse benthic macroinvertebrate community, submerged macrophytes (seagrasses), coastal salt marshes, oyster reef communities, and a variety of finfish (e.g., bay anchovy, batfish, seatrout, red drum, spot, striped mullet) and shellfish (e.g., squid, shrimp, stone crab, blue crab) (FPC 1985).

Concerns about the impacts of the Crystal River Power Station on aquatic resources focus on thermal discharges and entrainment (Gardner 1990; Smallwood 1990). Based on data collected for the plant's 316(a) demonstration (FPC 1985), thermal effluents from the multiunit power station were considered by the Florida Department of Environmental Regulation (DER) to have substantially damaged the benthic macroinvertebrate and seagrass communities in a 1100-ha (2700-acre) mixing zone around the discharge canal (Olsen 1986). The DER also expressed concern about the entrainment by Crystal River Units 1, 2, and 3 of bay anchovies, crab larvae, and penaeid shrimp larvae. Conversely, DER agreed with the Florida Power Commission (FPC) conclusions that thermal discharges from Crystal River Units 1, 2, and 3 had enhanced productivity in the nearby salt marshes and increased the growth rates of oysters in areas moderately affected by heat.

Impacts to aquatic resources continue to be examined at this site as part of NPDES permit renewals. The Crystal River Station has recently been required by EPA to reduce total condenser cooling water withdrawals during a portion of the year [FPC, response to NUMARC survey (NUMARC)]. This flow reduction scheme would reduce the number of entrained organisms but would not reduce thermal effects. Installation of helper cooling towers would reduce thermal discharges from the Crystal River site (Charles Kaplan, Region 4 EPA, personal communication to G. F. Cada, ORNL, Oak Ridge, Tennessee, November 12, 1990).

F.5 SUMMARY

A detailed consideration of these once-through nuclear power plants indicates that many of the aquatic resources issues evaluated in the licensing stage have not materialized as significant problems. Even at facilities where impact potential is considered to be greatest, these impacts have been difficult to quantify. For example, while localized effects of phytoplankton entrainment or scouring of bottom sediments near the discharge structure have been demonstrated in some instances, such impacts have not precluded the maintenance of balanced, indigenous populations of shellfish, fish, and wildlife; and the regulatory agencies regard these effects as acceptable.

Conversely, these examples illustrate that the entrainment and impingement of fish and the discharge of heated effluents from once-through power plants continue to concern some regulatory and resource agencies. In some instances, the NPDES permit and 316(a) and (b) review processes have not been completed, and the acceptability of impacts or the need for mitigation are still under consideration. As noted in Section 4.2, those aquatic resources issues that have not been resolved to the satisfaction of EPA or the state water quality permitting agency as part of the discharge permitting process will need to be considered in the license renewal application.

F.6 ENDNOTES

1. The discrepancy between the estimates in the FES and the estimates provided by AP&L are probably explained in large part by one or both of two possibilities. First, comparison of information in Zweiacker et al. (1977) with AP&L's estimate suggests that AP&L's estimate may consist of actual collections of impinged fish during sampling that covered 6 days per week during 6 weeks per quarter, without scaling up to estimate impingement during periods not sampled. Second, the first year of operation represented by AP&L's estimates may not correspond exactly to the period for which estimates were made in the FES.

2. The National Reservoir Research Data Bases are available from Southeastern Wildlife and Fisheries Statistics Project, Institute of Statistics, North Carolina State University, Box 8203, Raleigh, NC 27605–8203. Documentation describing the data is not currently available. In addition, other caveats apply: serial correlation is possible and may interfere with the analysis, and other assumptions (e.g., equality of the within-group covariance matrices) sometimes were not satisfied or could not be tested.

3. The (calculated) estimates for both entrainment and impingement at the proposed plants appear to be too low by at least a factor of 8 in relation to the regression equations and the stated number and capacity of the new plants.

The reason for this apparent discrepancy cannot be determined from the information available (John Kelso, Great Lakes Biolimnology Laboratory, personal communication to S. W. Christensen, ORNL, Oak Ridge, Tennessee, January 28, 1991).

4. The staff presents these results from Jensen et al. but notes that it is not able to reproduce approximately the estimates of percentages impinged, even though seemingly sufficient information is provided in the paper. Insufficient information is provided to try to reproduce the estimates of percentages entrained.

5. The staff noted that the commercial catch estimates presented and used by Jensen et al. for alewife in Lake Michigan, but not for smelt, differ typically by a factor of 2 to 4—depending on the year—from those given by Scott-Wasilk et al. These differences result from the exclusion from the Scott-Wasilk et al. table of commercial catch data for alewife in Green Bay.

6. The source of the variation in the entrainment and impingement coefficients is not clear, but it may be derived from year-to-year variation in biomass in the models.

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