هـيئة البيئة - أبوظبي
Environment Agency - ABU DHABI

# Technical Guidance Document for Fish Entrainment and Impingement Studies

## EAD-EQ-PCE-TG-14

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| Environmental Quality Sector | *Corporate Management Representative | Secretary General |
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* Refer to SG Circular S.G/C-08/12 Concerning Appointment and Responsibilities of the Corporate Management Representative at the Environment Agency – Abu Dhabi.

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# Fish Entrainment and Impingement Studies

## List of Abbreviations

| | |
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| BTA | Best Technology Available |
| CalCOFI | California Cooperative Oceanic Fisheries Investigations |
| E&I | entrainment and impingement |
| EA | Equivalent Adult |
| EAD | Environment Agency – Abu Dhabi |
| EAP | Environmental Action Plan |
| EDP | Environmental Development Plan |
| EIA | Environmental Impact Assessment |
| EPA EAD | Environmental Permit Application |
| EPA US | Environmental Protection Agency – U.S. |
| EPRI | Electric Power Research Institute |
| ER | Environmental Report |
| EY | Equivalent Yield |
| FAO | Food and Agriculture Organization |
| FH | Fecundity Hindcasting |
| PER | Preliminary Environmental Review |
| PF | Production Foregone |
| SEA | Strategic Environmental Assessment |
| SEMAP | Southeast Area Monitoring and Assessment Program |
| TOR | Terms of Reference |

## Definitions of Terms

**Intake structure—**the total physical structure and any associated constructed waterways used to withdraw water from the source water body for the purpose of condenser cooling, desalinization, or other uses.

**Entrainment—**the drawing of small marine organisms present in the source water body through the intake structure and into the condenser cooling, desalinization, or other water use systems.

**Impingemen**t**—**the trapping of organisms too large to be entrained against the screening systems that prevent debris from entering the facility with the withdrawn water.

**Ichthyoplankton**—eggs and larvae of fish.

## Purpose of This Guidance Document

This guidance document is intended to establish policies and procedures related to the preparation and submission of entrainment and impingement (E&I) studies at proposed marine water intake structures in Abu Dhabi. E&I studies are conducted in order to understand the potential impacts associated with marine water intake structure and activities, evaluate potential mitigation measures, and select effective options to reduce or compensate for impacts from E&I. Such studies may be required at new facilities or existing facilities that require significant intake of marine water due to the potential impacts to marine biological resources through entrainment or impingement.

E&I studies, if required, may be performed as part of the Environmental Report (ER) development process, and the resulting E&I report would be included as an appendix to the ER. Environmental reports for which such studies might be required include Environmental Impact Assessments (EIA), Preliminary Environmental Review (PER), and Strategic Environmental Assessments (SEA). Throughout this guidance, all such reports will be referenced as ERs. Additionally, EAD may request an E&I study to be conducted and reported upon outside of the ER process if there is reason and significance to warrant an evaluation of E&I impacts on the environment. This document:

- reviews the applicability of E&I studies to new and existing facilities,
- provides example field study methodology and implementation strategies to effectively monitor and characterize seasonal patterns of ichthyoplankton and fish abundance in the vicinity of a proposed intake structure,
- discusses analysis and interpretation techniques for data obtained from field studies,
- reviews selection of intake technologies (and other mitigation measures) for minimizing adverse impacts of E&I, and
- outlines EAD requirements for preparation and submission of study results and findings.

# Section I. Background Information

This section provides a description of E&I studies, identifies the types of facilities that have the potential for significant environmental impacts due to E&I, and the conditions under which an E&I study would be required for submission with an ER.

## Objective of an E&I Study

An E&I study is an assessment of the potential impacts from E&I, together with an evaluation of alternative mitigating measures and alternatives for reducing E&I. Entrainment or impingement of large numbers of marine organisms can occur as a result of large-volume water withdrawals, such as those associated with power plant condenser cooling, desalinization, or other purposes. Entrained organisms can be injured or killed by heat, physical stress, or chemicals used to prevent biofouling of system components. Impinged organisms may be killed or injured due to physical abrasion or stress caused by being trapped against intake screens. The types of organisms subject to E&I include phytoplankton, zooplankton, and early life stages of fish and shellfish. Depending on the numbers of organisms lost relative to the abundance and reproductive capacity of susceptible populations, E&I can cause a variety of adverse impacts, including reductions in the abundance and productivity of marine populations, reductions in harvests of valued finfish and shellfish species, and reductions in the forage bases available to predator species.

The purpose of an E&I study is to characterize the types of organisms susceptible to E&I at a proposed facility, quantify, to the extent possible, the number of organisms that may be entrained or impinged on an annual basis, and to provide insight on the selection of intake technologies and other mitigation measures for minimizing adverse impacts of E&I. Any such studies should be performed prior to or concurrently with other components of the ER, so that the information provided can inform project managers concerning E&I mitigation needs early in project planning. Occasionally, EAD may request that an E&I study be performed outside of the ER process, in which case the timing and schedule would be dependent upon communications between EAD and project proponent.

## Applicability and Approach

EAD may require that E&I characterization studies be applied at proposed and existing facilities that withdraw or have the potential to withdraw large quantities of water from marine environments. The key criterion for determining applicability of this guidance is the volume of water withdrawn. Power plants and desalinization plants have been identified as large-volume water users; however, E&I characterization studies may be required at other types of facilities that also withdraw water from marine environments. A volume of 2 million gallons (7.6 million liters) per day has been identified by the U.S. Environmental Protection Agency (EPA) as a threshold beyond which regulations governing cooling water intake structures become applicable. Facilities in EAD with the potential for withdrawing this volume should be prepared to undertake an E&I study. Other criteria, such as the presence of species of high ecological value, may also warrant EAD to request that the proponent conduct an E&I study.

Developers of facilities for which this guidance is applicable are required to evaluate the potential adverse impacts of E&I at those facilities and to minimize those impacts through a combination of mitigating measures, including minimization of cooling water withdrawals, siting of intake structures in locations that minimize potential E&I, and selection of intake structures that minimize harm to potentially entrained or impinged organisms. In some cases, compensatory mitigation measures may also be required. Documents describing best practices for minimizing E&I have been published in the United States, Canada, and the United Kingdom.

## Regulatory Framework

EAD has set specific requirements to be enforced in Abu Dhabi that ensure integration of environmental assessment, sustainability principles, and impact minimization at all levels of planning and execution of government and private developments. EAD stresses the importance of assessing and mitigating potentially adverse impacts, such as those associated with impingement and entrainment, under Federal Law No. 24/1999. Consistent with currently proposed EPA regulations (EPA, 2011), power plants and desalinization facilities in Abu Dhabi should employ Best Technology Available (BTA) for minimizing impingement mortality if water withdrawals exceed 2 MGD and should perform a site-specific E&I study if water withdrawals exceed 125 MGD.

## Preparation and Submission

The proponent of the proposed project is responsible for preparing and submitting an E&I report, in accordance with the content requirements outlined in Section II of this Technical Guidance Document. When an E&I study is conducted as part of the ER process, the Entrainment and Impingement Characterization sections as well as all other ER documents should be produced by an EAD–approved and –registered environmental consultant operating within Abu Dhabi Emirate. A current list of registered consultants can be obtained from EAD's Customer Service or from EAD's Web site at http://www.ead.ae. The proponent should refer to the *Technical Guidance Document for Submission of Environmental Permit Applications and Environmental Studies* (EAD, 2010h) for guidance regarding the required number of copies and format of EIAs.

The proponent of the proposed project is also responsible for preparing and submitting the E&I monitoring reports for EAD's review, if required. The monitoring reports should be prepared by an EAD–approved and –registered environmental consultant operating within Abu Dhabi Emirate and should adhere to the layout and content requirements outlined in Section II of this Technical Guidance Document.

# Section II. Format and Content of E&I Study Report as Part of an Environmental Impact Assessment (EIA)

This section describes the content and format for the E&I Study Report. When an E&I is submitted as part of the ER process, the study should be summarized within the ER document and appended to the ER document when it is submitted to the EAD.

## 1. Project or Industry Title Page

This page should list the project the E&I study was prepared for, the contact information of the proponent and consultant, and the date that the study was submitted.

## 2. Distribution List

Distribution list for the E&I study

## 3. Introduction

The introduction should briefly describe the E&I study, project rationale, and the status and schedule of the project.

## 4. Project Description

This section specifies information the proponent should provide concerning the location, design, and other characteristics of the facility.

## 4.1 Location and Facility Description

Much of the information required in this section is likely to be available from the EIA or other ER documents. Any such information may be incorporated by reference to the ER documents.

### *4.1.1 Site location and layout*

- Map showing relationship of proposed intake location and water withdrawal system to other major facilities within a 50-mile radius.
- Detailed map showing local topographic and hydrological features at the site, with specific location of intake structure with respect to shoreline and to other on-site structures.

### *4.1.2 Intake structure design*

- Detailed description, with maps and diagrams, of the location of the structure with respect to other components of the cooling system, desalinization system, or other systems for which water is being withdrawn; location in the waterbody; configuration, including intake and discharge canals or channels; proposed screening devices, fish by-pass and handling facilities; other relevant system-specific data.
- Detailed descriptions of pumps, including design details, pump capacity, and number of pumps.
- Planned use of biocides, including location of introduction, description and toxicity of biocide used, timing and duration of use, and estimated concentration of biocide in discharged water.

### *4.1.3 Intake withdrawal rate*

- Maximum withdrawal rate; seasonal variations in withdrawals
- Average and maximum approach and through-screen water velocities, by depth

### *4.1.4 Source water body description*

This section specifies information that contractors should provide concerning the characteristics of the waterbody from which water will be withdrawn. Most of this information may already have been collected to support the ER. Include a brief description in each sub-section below.

#### 4.1.4.1 Current/speed/direction profile

#### 4.1.4.2 Tidal range

#### 4.1.4.3 Bathymetry

#### 4.1.4.4 Biological populations and communities in the vicinity of the facility

#### 4.1.4.5 Representative important species

## 4.2 Scope

This section describes activities that were conducted as part of an E&I study. The E&I study should be sufficient to provide scientifically valid conclusions concerning the potential impacts of E&I if the facility is built and operated as designed. Prior to initiating the study, project proponents must submit a sampling plan (see Annex A) to EAD for approval.

### 4.2.1 Biological survey design for new sites

Intake structures at new sites for which E&I studies are required by EAD are performed concurrent with other biological studies required as part of the environmental reporting process. The following information concerning the E&I study should be provided in the E&I report for new sites. Annex A provides an example outline for a sampling plan to be submitted to EAD for approval prior to the initiation of field studies. The sampling stations, sampling gear, sampling frequency and effort, and sampling procedures should be documented in the sampling plan and approved by EAD prior to conducting the study.

#### 4.2.1.1 Sampling station selection

The report should identify the sampling stations at which samples were collected for the purpose of assessing potential impacts of E&I. The exact number and locations of these stations should be selected to consider the presence of special species or habitats, such as reefs or seagrass beds within the study area. If applicable, the stations should be based on the information provided by biological surveys performed to support the ER process.

The rationale for station selection should be provided in this section. The geographic coordinates of all stations should be specified according to the requirements of EAD's Guidelines for Baseline Data.

#### 4.2.1.2 Sampling gear

This section should describe the sampling gear used to collect ichthyoplankton samples for the purpose of E&I assessment. Sampling gears and methods suitable for collecting marine ichthyoplankton have been developed by the United Nations Food and Agriculture Organization (FAO) and the U.S. Southeast Area Monitoring and Assessment Program (SEMAP), and the California Cooperative Oceanic Fisheries Investigations (CalCOFI). The use of any gears other than those used by one or more of these organizations should be justified and supported with results of a study comparing the effectiveness of the proposed alternative gear to the effectiveness of one of the standard gears.

#### 4.2.1.3 Sampling frequency/effort

This section should document the sampling frequency and effort used in the study. To properly characterize the ichthyoplankton present in the vicinity of the site over the annual cycle, sampling at all stations should be conducted monthly for a minimum of 3 years (EPA, 1977). The sampling effort should be sufficient to characterize the abundance of ichthyoplankton at each station over at least one 24-hour period per month.

#### 4.2.1.4 Sampling procedure

This section should document the procedures used to collect each sample, including the net deployment method, the number of tows performed, the duration of each tow, and the method used to calculate the volume of each sample. Guidance on sampling procedures can be obtained from sampling procedures recommended by the FAO, SEAMAP, and CalCOFI.

### 4.2.2 Biological survey design for new intake structures at existing sites

With the exception of information obtained from monitoring of impingement and entrainment at existing intake structures located at the site, the information included in an E&I report for an existing site should be the same as for a new site. If an E&I study has previously been performed at a site for which a new intake structure (e.g., to support a new power generation or desalinization unit) is being proposed, the proponent should discuss with EAD whether additional E&I monitoring is required. It should be noted that even if additional monitoring events are not requested, an E&I study may still be required by EAD to determine whether adverse impacts are anticipated and if additional mitigation will be needed. If there have been no previous E&I studies at the site, then E&I sampling and an E&I study may be necessary.

#### 4.2.2.1 Impingement monitoring

If an impingement monitoring study has been performed, the E&I report should describe methods used to characterize the number of fish impinged annually at the site, based on impingement monitoring data. The methods and results of the impingement monitoring study should be documented in an annex to the E&I report.

#### 4.2.2.2 Entrainment monitoring.

If an entrainment monitoring study has been performed, the E&I report should describe methods used to characterize the number of fish eggs and larvae entrained annually at the site, based on entrainment monitoring data. The methods and results of the entrainment monitoring study should be documented in an annex to the E&I report.

### 4.2.3 Sample handling and analysis

This section of the report should document the methods used to preserve and analyze all ichthyoplankton samples. Sample preservation and field analysis should follow procedures recommended by the FAO (Smith and Richardson, 1997), SEAMAP, and CalCOFI. The analysis procedure should permit fish eggs and larvae to be identified and enumerated to the lowest taxonomic level (i.e., family, genus, species) possible using standard light microscopic analysis and standard published identification keys.

### 4.2.4 QA/QC procedures

This section of the report should summarize QA/QC procedures employed to ensure integrity of samples; proper identification of the specific locations, dates, and times at which each sample was collected; and the accuracy of sample analysis. Details concerning these QA/QC procedures should be provided in an annex to the E&I report.

### 4.2.5 Data formatting

An attachment to the E&I report should provide (1) copies of all field logs, field processing forms, and laboratory analysis forms, and (2) tables and spreadsheets listing, for each sample, the sampling time, sample start time, sample stop time, estimated sample volume, and numbers of each identifiable taxon collected. All tabular and non-tabular data should be submitted to EAD in the formats prescribed in EAD's *Technical Guidance Document for Submission of Environmental Permit Applications and Environmental Studies* (EAD, 2010h).

### 4.2.6 Data analysis

This section of the report should specify the types of data summaries and assessment approaches used in interpreting the data collected for the E&I study. At a minimum, this analysis would include estimation of the abundance, by taxon and life stage, of ichthyoplankton at each station over the study period, together with estimates of potential annual entrainment losses calculated using information on ichthyoplankton densities and water withdrawal rates. In performing these calculations, maximum design withdrawal rates should be used. If an impingement monitoring study has been performed, then the analysis should also include estimation of annual numbers of fish impinged, by taxon. To the extent feasible, analysis should also include estimation of E&I losses expressed as equivalent adults.

Guidance on equivalent adult analysis is provided in three reports from the Electric Power Research Institute (EPRI): *Extrapolating Impingement and Entrainment Losses to Equivalent Adults and Production Foregone* (EPRI Report 1008471, 2004), *Parameter Development for Equivalent Adult and Production Foregone Models* (EPRI Report 1008832, 2005), and *Comprehensive Update of Fish Life History Parameter Values* (EPRI Report 1023103, 2012). Additional methods for evaluating the effects of E&I on aquatic life are described in an additional report from EPRI *Catalog of Assessment Methods for Evaluating the Effects of Power Plant Operations on Aquatic* Communities (EPRI Report TR-112013, 1999). Regardless of which methods are used, all assumptions and parameter values used in the analyses should be documented in an annex to the E&I report. An overview of the recommended methods is provided in Annex B to this guidance.

# 5. Environmental Impact Description

This section should discuss the results of all analyses of data relating to adverse impacts of E&I on susceptible fish populations. Estimated monthly and E&I losses, by taxon and life stage, should be provided in tabular form. Statistical analyses of sampling data should be used to estimate confidence means, variances, and confidence intervals around E&I loss estimates.

If equivalent adult analysis has been performed for any species, E&I losses for those species, expressed in terms of equivalent adults, should be provided. If feasible, equivalent adult estimates for commercially harvested species should be further converted to estimates of potential lost harvest using models described in EPRI Report 1008471 (2004). If other methods documented in EPRI TR-112013 (2012) are used, results should be provided in the form of tables or figures. Uncertainties concerning estimates of equivalent adults, lost harvest, or other model-derived metrics should be addressed by performing alternative calculations using reasonable ranges of model parameter values.

In interpreting the results described above, the following types of adverse impacts should be discussed:

## 5.1 Direct Impacts on Populations Susceptible to E&I

These impacts include reductions in the abundance or changes in the distribution of populations of fish with life stages that are (or are likely to be) entrained or impinged.

## 5.2 Indirect Impacts on Other Ecosystem Components

These impacts include food-web changes in the abundance or productivity of prey or predator species due to the entrainment or impingement of susceptible species.

### 5.3 Factors Influencing Susceptibility of Populations and Ecosystems to Adverse impacts of E&I

These factors primarily relate to the spatial distributions of various life stages with respect to an intake structure. Identification of such factors can aid in designing mitigating measures to reduce adverse impacts of E&I.

## 6. Evaluation of Intake Technologies for reducing E&I

This section will briefly describe available alternatives for reducing or minimizing E&I and identify alternatives that are potentially applicable to the site for which the E&I assessment was performed. U.S. and international technical guidance documents are the primary source of information concerning these technologies. Factors affecting technology selection are discussed in Annex C to this guidance. The contractor will use the information provided in Annex C to recommend (1) whether existing or proposed intake structures adequately protect marine resources from E&I impacts, and (2) if mitigation is needed, which alternative technologies would be most appropriate for reducing E&I at the site. Consistent with currently proposed EPA regulations and international best practices, if the intake velocity at a facility can be reduced to 0.5 feet per second or lower, no additional technologies for reducing impingement are required. For desalinization plants, some of the entrainment reduction technologies (e.g., flow reductions, seasonal outages, and cooling towers) would not be applicable. However, technologies such as cylindrical wedgewire screens and aquatic life barriers would still be applicable. For both E&I, mitigation in the form of habitat restoration or other enhancements of marine resources could, at the discretion of EAD, be employed as an alternative to E&I reduction.

### 6.1 Overview of Available Technologies for Reducing Entrainment

This section should provide brief descriptions of the technologies and operational procedures that were considered for the purpose of reducing entrainment at the facility. A review of the current status of development of technologies for reducing entrainment is provided in EPRI report 1014934: *Fish Protection at Cooling Water Intake Structures: a Technical Reference Manual* (EPRI, 2007). At a minimum, the alternatives discussed should include those identified in the following subsections:

#### *6.1.1 Intake location*

Construction of an off-shore intake structure connected to the facility through a buried piping system can greatly reduce entrainment in situations where ichthyoplankton densities offshore are substantially lower than densities along the shoreline.

#### *6.1.2 Operational modifications*

Under some circumstances, changes in facility operations can reduce entrainment by reducing water usage during critical periods in which ichthyoplankton densities in the vicinity of the facility are high (e.g., spawning periods for important fish species).

##### *6.1.2.1 Flow reductions*

Depending on the design of the pumps used for water withdrawal, entrainment can be reduced by reducing the rate of water withdrawal during critical periods.

##### *6.1.2.2 Seasonal outages*

Facilities can reduce entrainment by ceasing operations during critical periods.

### 6.1.3 Intake technology alternatives

The following are examples of intake technologies that have been demonstrated to greatly reduce entrainment under many circumstances. All three technologies are applicable to power plants; only cylindrical wedgewire screens and aquatic life barriers are applicable to desalinization facilities.

#### 6.1.3.1 Closed-cycle cooling (cooling towers)

Closed-cycle cooling systems reduce entrainment by reducing the water withdrawn for cooling purposes by 80 to 100% as compared to conventional once-through cooling (EPA, 2011). The reduction is achieved through the use of cooling towers that reject waste heat through evaporative cooling (wet cooling towers), radiative and convective cooling (dry cooling towers), or a combination of cooling processes (hybrid cooling towers).

#### 6.1.3.2 Cylindrical wedgewire screens

Cylindrical wedgewire screens are applicable both to power plants with once-through cooling systems and to desalinization plants. They reduce entrainment by greatly reducing the velocity of water drawn through the screens, by preventing organisms larger than the widths of the screen slots (typically 1-6 mm) from passing through the screens, and by promoting behavioral avoidance of the screens by organisms able to detect changes in flow velocities near the surface of a screen.

#### 6.1.3.3 Aquatic life barriers

Aquatic life barriers are applicable both to power plants with once-through cooling systems and to desalinization plants. They reduce entrainment by withdrawing water through a porous membrane with pores smaller than the smallest species and life stages for which entrainment reduction is needed.

Additional information on these technologies and others are available in EPRI report 1014934: *Fish Protection at Cooling Water Intake Structures: a Technical Reference Manual* (EPRI, 2007).

## 6.2 Overview of Available Technologies for Reducing Impingement

This section should provide brief descriptions of the technologies and operational procedures that were considered for the purpose of reducing impingement at the facility. A review of the current status of development of technologies for reducing impingement is provided in EPRI report 1014934: *Fish Protection at Cooling Water Intake Structures: a Technical Reference Manual* (EPRI, 2007). At a minimum, the alternatives discussed should include those identified in the following subsections:

### 6.2.1 Intake location

Construction of an off-shore intake structure connected to the facility through a buried piping system can greatly reduce impingement in situations where fish densities offshore are substantially lower than densities along the shoreline.

### 6.2.2 Operational Modifications

Under some circumstances, changes facility operations can reduce impingement by reducing water usage during critical periods in which fish densities in the vicinity of the facility are high (e.g., spawning periods for important species).

#### 6.2.2.1 Flow reductions

Depending on the design of the pumps used for water withdrawal, impingement can be reduced by reducing the rate of water withdrawal during critical periods.

#### *6.2.2.2 Seasonal outages*

Facilities can reduce impingement by ceasing operations during critical periods.

### *6.2.3 Intake technology alternatives*

All three of the entrainment-reducing technologies described in section 6.1.3 would be expected to reduce impingement to very low levels. However, for facilities at which impingement is a potential concern but entrainment is not expected to be significant, the technologies described below can substantially reduce impingement mortality at a far lower cost than the technologies discussed in section 6.1.3.

#### *6.2.3.1 Fish barrier nets*

Fish barrier nets are coarse-mesh nets that are installed in front of an intake structure to prevent fish from entering the structure and becoming impinged. They reduce impingement both by preventing fish from entering the intake and by reducing the velocity of water approaching the net face below a velocity at which fish can become trapped on the screen. The installation of fish barrier nets at existing facilities requires no modification of the existing intake structure.

#### *6.2.3.2 Ristroph screens and other similar screening systems with fish returns*

Ristroph screens are conventional travelling screens that have been modified so that fish impinged on the screens can be removed with minimal stress and mortality. Ristroph screens have water-filled lifting buckets that collect the impinged organisms and transport them to a fish return system. Several other more recently developed screening concepts are described in EPA’s most recent Technical Development Document on water intake (EPA, 2011). All of these screening systems operate in conjunction with fish return systems that return impinged fish to the source water body.

#### *6.2.3.3 Fish diversion systems*

Angled screens, inclined screens, and louver systems are technologies designed to divert fish away from intake structures and into fish return systems. Although most applications of such systems have been at hydropower and water diversion facilities, these systems may be applicable at some other types of facilities.

#### *6.2.3.3 Behavioral deterrents*

Bubble screens, strobe lights, and acoustic diversion systems have been deployed at many intake structures for the purpose of deterring fish from entering intake structures. These technologies have been found to be effective for some, but not all, species and environmental conditions. They are relatively inexpensive add-ons to conventional once-through cooling systems; however, site-specific testing is necessary to determine their efficacy for the mix of species impinged at a facility.

Additional information on these technologies and others are available in EPRI report 1014934: *Fish Protection at Cooling Water Intake Structures: a Technical Reference Manual* (EPRI, 2007).

## 6.3 Selection of Intake Technologies

This section will document the rationale for selection of the intake technology proposed for the facility. The appropriateness of any given technology for application to a facility depends on both biological and engineering factors.

Relevant biological factors include the importance of local marine habitats as spawning and nursery areas for important fish species, the densities and seasonal patterns of occurrence of ichthyoplankton and fish measured in the E&I survey programs discussed in sections 4.2.1 and 4.2.2 above, and the estimates of total E&I and adult equivalent losses discussed in section 5 above.

Relevant engineering factors include the location of the intake structure relative to the shoreline, the expected withdrawal rate of the facility, and site-specific factors that affect the feasibility of one or more intake technologies.

Annex C provides a discussion of factors to be evaluated in selecting among the technologies discussed in section 6.2.3 above.

# 7. Monitoring and Auditing

This section will describe any long-term monitoring requirements related to E&I that are not already included in quarterly monitoring specified in ER documents. The monitoring to be discussed in this section is limited to ichthyoplankton and fish sampling and does not include any water quality monitoring that may be required by EAD. The need for supplemental monitoring will depend on the intake technology employed at the facility. More comprehensive monitoring is expected for facilities that select once-through cooling with minimal mitigation of E&I than for facilities that select technologies with greater potential for reducing E&I.

## 7.1 Environmental Performance Monitoring

This section will document the E&I performance monitoring proposed for the facility. Information that should be presented includes:

- the program objectives, attributes, and indicators and/or conditions that will be measured;
- monitoring methodology that will be used;
- analyses that will be conducted; and
- equipment that will be used in the monitoring program.

For facilities with conventional once-through cooling, performance monitoring should include (1) monitoring of ichthyoplankton abundance as close to the intake structure as possible given sampling feasibility and safety concerns, and (2) monitoring of fish impingement through collection of impinged fish that have been washed off the intake screens. Monitoring of screening technologies intended to reduce E&I below levels expected from conventional systems should focus on evaluating the efficacy of the technologies employed (i.e., comparison of the levels of E&I achieved through implementation of the technology to levels expected without the technology).

## 7.2 Reporting Requirements

This section will document the contents and schedule for reporting results of environmental performance monitoring to EAD. At a minimum, each report should include estimates of annual total E&I expressed both as total counts, by taxonomic group and life stage, and, where life history data permit, estimates of total equivalent adult losses and potential harvest foregone to fisheries. If technologies intended to reduce entrainment or impingement have been installed, then the report should include an evaluation of the effectiveness of those technologies. The proponent should propose a schedule for annual report production, allowing for the time necessary for laboratory processing of ichthyoplankton samples and subsequent data analysis.

# 8. Long-Term Management

This section summarizes long-term plans for monitoring adverse impacts of E&I on local fish populations and communities, recognizing that a minimum of 5 years of operational data are necessary to determine whether the existing intake technology is adequate for protecting marine resources in the vicinity of the facility or whether additional mitigation is needed to reduce adverse impacts. At the discretion of EAD, additional environmental studies beyond the performance monitoring discussed in

Section 7 of this guidance may be required. Full documentation of plans for conducting a 5-year review and evaluating additional mitigation measures will be provided in an Environmental Development Plan (EDP) submitted to EAD.

At the discretion of EAD, long-term monitoring and assessment may continue for one or more additional 5-year periods, evaluating the efficacy of supplementary mitigation measures undertaken after the first 5-year review.

### 8.1 Five-Year Review of Adverse Impacts of E&I

This section will summarize the data and methodologies that will be used in the 5-year review to assess adverse impacts to marine resources. Details will be provided in the EDP.

### 8.2 Assessment of Supplementary Mitigation Alternatives

This section will identify the supplementary mitigation measures that will be considered as part of the 5-year review. These could include one or more of the alternative intake technologies discussed in Annex C. In addition to intake technology modifications, compensatory mitigation measures that would improve marine habitat quality and fish production in the vicinity of the facility could be evaluated. All such measures should be identified in the EDP.

## References

Electric Power Research Institute (EPRI). 1999. Catalog of assessment methods for evaluating the effects of power plant operations on aquatic communities. EPRI Report TR-112013. EPRI, Palo Alto, CA.

EPRI. 2004. Extrapolating impingement and entrainment losses to equivalent adults and production foregone. EPRI Report 1008471. EPRI, Palo Alto, CA.

EPRI. 2005. Parameter development for equivalent adult and production foregone models. EPRI Report 1008832. EPRI, Palo Alto, CA.

EPRI. 2012. Comprehensive update of fish life history parameter values. EPRI Report 1023103. EPRI, Palo Alto, CA.

Environment Agency of the United Kingdom. 2005. Screening for intake and outfalls: a best practice guide. Science Report SC030231.

Environmental Protection Agency (EPA). 2011. Technical development document for the proposed section 316(b) Phase II Facilities Rule. March 28, 2011. EPA Report number EPA-821-R-11-001. EPA, Washington, DC.Body Text.

# Annex A: Ichthyoplankton Sampling and Analysis Plan Outline

This annex outlines the recommended elements for an ichthyoplankton sampling and analysis plan. The proponent's sampling plan should be submitted to EAD prior to the conduct of field studies used to support an E&I assessment.

## 1. Roles and responsibilities

The plan should identify all contractors and subcontractors who will participate in sample collection and analysis, including laboratories that will perform taxonomic identifications of ichthyoplankton and invertebrates. The role of each contractor should be specified, and the contractor responsible for production of the E&I report should be identified. Statements of qualifications of each contractor should be included as attachments to the plan.

## 2. Sampling locations

The plan should identify the sampling stations to be included in the study, with geographic coordinates specified according to the requirements of EAD's Guidelines for Baseline Data. The exact number and locations of these stations should be selected based on biological surveys performed to support the ER process, considering the presence of special habitats such as reefs or seagrass beds within the study area. The rationale for station selection should be provided. The geographic coordinates of all stations should be specified according to the requirements of EAD's Guidelines for Baseline Data. One or more maps showing the locations of sampling stations should be provided as an attachment to the plan. If the study is being performed at an existing facility, one of the sampling stations should be located within the intake canal or, for shoreline intakes, as close to the intake structure as is feasible.

## 3. Collection method

The plan should describe the sampling gear used to collect ichthyoplankton samples for the purpose of E&I assessment. Sampling gears and methods suitable for collecting marine ichthyoplankton have been developed by the United Nations Food and Agriculture Organization (FAO) and the U.S. Southeast Area Monitoring and Assessment Program (SEMAP), and the California Cooperative Oceanic Fisheries Investigations (CalCOFI). For example, SEMAP sampling is performed with bongo net frames, with a net mesh size of 0.333 mm and a minimum diameter of 0.6 m. Each net is fitted with a flowmeter so that accurate sample volumes can be calculated. The use of any gears other than those used by SEMAP, FAO, or CalCOFI should be justified and supported with results of a study comparing the effectiveness of the proposed alternative gear to the effectiveness of one of the standard gears.

## 4. Sampling frequency and effort

The plan should specify the frequency with which samples will be collected. It is expected that sampling will be performed at each station a minimum of once per month, for a minimum of 3 years. The sampling effort should be sufficient to characterize the abundance of ichthyoplankton at each station over at least one 24-hour period per month. If possible, all samples should be collected at night to take advantage of vertical nighttime migrations and to minimize avoidance of the sampling gear. A minimum of two samples per station per sampling period should be collected; however, EAD may at its discretion require a larger number of samples.

## 5. Sampling procedure

The plan should document the procedures used to collect each sample, including the net deployment method, the number of tows performed, the duration of each tow, and the method used to calculate the volume of each sample. Guidance on sampling procedures can be obtained from sampling procedures recommended by the FAO, SEAMAP, and CalCOFI. Diagonal bottom-to-surface tows provide estimates of ichthyoplankton abundance integrated over the entire water column and are the preferred approach for sampling performed to support an E&I study. The sampling plan should provide a rationale for using a different approach.

## 6. Sample handling and analysis

The plan should document the methods used to preserve and analyze all ichthyoplankton samples. Sample preservation and field analysis should follow procedures recommended by the FAO (Smith and Richardson, 1997), SEAMAP, and CalCOFI. The plan should document the chain-of-custody procedures used to guarantee sample integrity from the time they are collected until all laboratory analyses are completed. The laboratory analytical procedure should permit fish eggs and larvae to be identified and enumerated to the lowest taxonomic level (i.e., family, genus, species) possible using standard light microscopic analysis and standard published identification keys.

## 7. QA/QC procedures

The plan should document the QA/QC procedures that will be employed to ensure integrity of samples; proper identification of the specific locations, dates, and times at which each sample was collected; and the accuracy of taxonomic identifications and abundance counts.

## 8. Methodological references

The plan should list all ichthyoplankton identification keys that will be used, as well as all general references concerning sample methodologies that were consulted during preparation of the plan

## 9. Data analysis methods

The plan should specify the statistical methods and analytical models (e.g., equivalent adult models) that will be used to analyze the data. Key species (e.g., commercially important fish species expected to be present in the vicinity of the facility should be identified) and methods to be used to quantify potential impacts on those species should be discussed. The plan should summarize available information concerning the life histories of these species and identify sources of data that can be used to estimate key life history parameters.

## 10. Schedule and deliverables

The plan should specify a schedule for all project activities, including sample collection, sample analysis, data evaluation, and completion of a study report.

# Annex B:
# Overview of Methods for Equivalent Adult Analysis

Regulatory agencies in the United States, Canada, and the European Union promote minimization of E&I losses of fish at water intake structures, subject to a requirement that the costs of reducing those losses must not be disproportionately high relative to the benefits of the reductions. One of the most common approaches for evaluating the benefits of reducing these losses of early life stages is to extrapolate the losses to equivalent reductions in numbers of adult fish. Equivalent adult models do not require site-specific data on the distribution or abundance of vulnerable populations, and they can be applied at any power plant for which entrainment or impingement losses can be estimated.

Two approaches to equivalent adult modeling have been developed. The first approach, termed the forward projection (FP) approach, uses estimates of age or stage-specific survival fractions to scale E&I losses to numbers of adults surviving to some future age, termed the "age of equivalence." The second approach, termed here the fecundity hindcasting (FH) approach, uses estimates of fractional survival from the egg stage to the stage/age of entrainment or impingement to calculate the number of female fish required to produce the lost fish. An extension to equivalent adult (EA) analysis, termed equivalent yield (EY) analysis, uses standard fisheries data and modelling methods to translate equivalent adult losses into equivalent reductions in harvest of exploited fish stocks. A complementary modelling approach, termed production foregone (PF) analysis, has been developed for estimating the potential reduction in prey biomass available to predators due to E&I of forage fish species.

All of the above models rely on conservative assumptions and are highly sensitive to uncertainties in input parameter values. None can be independently validated using site-specific data. Hence, although EA, EY, and PF models can be very useful for interpreting E&I losses in an ecological or human use context, significant care is needed both in model selection and in model parameterization to ensure that the results are credible. Guidance on the use of these models, including methods for estimating life history parameters for marine, estuarine, and freshwater fish species, is available in three reports prepared by the Electric Power Research Institute (2004, 2005, 2012).

# Annex C: Factors to Consider in Intake Technology Selection

A variety of factors affect the feasibility and relative environmental benefits of alternative intake technologies. Site-specific engineering feasibility and cost issues are beyond the scope of this guidance document. Detailed discussions of these factors are provided in technical guidance documents developed by the U.S. Environmental Protection Agency (2011) and the UK Environment Agency (2005). This annex briefly summarizes biological and technology development factors that can be considered when selecting an intake technology for a new facility or identifying potential mitigating technologies for existing facilities.

The intake technologies discussed in this guidance vary greatly with respect to cost, feasibility, state of development, and effectiveness for reducing E&I. Conventional travelling screens that are washed only as dictated by debris build-up are the least expensive and most widely used technology, and provide the least protection to ichthyoplankton and fish susceptible to E&I. For this reason, such screens are generally considered a “baseline” technology against which all other intake technologies are compared. Despite the absence of fish protection provided by these screens, they still may be an adequate choice for facilities that withdraw only low volumes of water or are located in regions where the population of ichthyoplankton and fish is low. In contrast, closed-cycle cooling systems are very expensive and are not feasible for all facilities; however, because they reduce water withdrawals by up to 95% compared to once-through cooling, they provide maximal reductions in E&I. The other technologies discussed in this guidance provide varying degrees of protection between these two extremes, and differ substantially with respect to efficacy at reducing E&I, feasibility, state of development, and suitability as additional mitigating measures for existing intake systems.

Biological factors that influence the degree of protection required include:

- the importance of local marine habitats as spawning and nursery areas for fish,
- the abundance of ichthyoplankton and fish in the vicinity of the intake structure,
- total measured or predicted E&I losses, and
- measured of predicted losses of valued species, expressed as equivalent adults or equivalent harvest.

Technological factors that influence the suitability of an intake technology with respect to fish protection include:

- potential for entrainment reduction, as compared to conventional travelling screens;
- potential for impingement reduction, as compared to conventional travelling screens;
- the state of development of the technology as determined from the number of facilities at which it has been used and the operational history of those facilities;
- site-specific constraints on the feasibility of the technology; and
- the suitability of the technology as an additional mitigating measure for existing intake structures.

The table below provides a general evaluation of the technologies discussed in this guidance with respect to the above technological factors. More detailed guidance concerning the capabilities and status of the available intake technologies can be found in UK Environment Agency (2005) and EPA (2011) technical guidance documents.

| | Conventional travelling screens | Travelling screens with fish return systems | Offshore intake structure | Cylindrical wedgewire screens | Aquatic life barriers | Flow reduction and outages | Barrier nets | Behavioral deterrents | Closed-cycle cooling |
|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Potential for entrainment reduction | N/A | N/A | M | H | H | M | N/A | N/A | H |
| Potential for impingement reduction | L | H | M | H | H | M | H | M | H |
| State of development | H | H | H | M | L | H | H | M | H |
| Feasibility constraint | L | M | M | M | H | L | L | L | M |
| Suitability as mitigating measure | N/A | H | L | M | L | H | H | H | L |

# Fish Entrainment and Impingement Studies

## Document Change History

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