Drawing on the long history of policy and project implementation for seawater intakes, a WateReuse Research Foundation study takes a lessons-learned approach to develop guidance on planning, designing, and delivering a successful habitat restoration mitigation program to compensate for the environmental effects of seawater intakes on marine plankton. **John Steinbeck** and **Joe Phelan** of the US-based marine environmental consulting firm Tenera Environmental report on the study's findings.

Habitat restoration to offset effects of desalination intakes

As the desalination of seawater becomes an increasingly desirable option for water planners, assessing and compensating for the environmental effects of the technology becomes increasingly pertinent. With expansion of the sector comes a need to develop a better understanding of the potential environmental effects and how planners and developers can best mitigate them. Large-scale implementation of desalination in countries with the most stringent environmental regulatory requirements is in its infancy, while subsequent environmental policies that will determine the regulatory processes imposed on the sector are still emerging. For example, California implemented a policy in May 2015 that requires compensation for any effects of desalination plant intakes.

One of the central environmental concerns associated with seawater desalination is the effect of entrainment on marine life. Entrainment occurs when small plants and animals that live suspended in the water column for part or all of their life cycle (called plankton) are drawn into the intake of a desalination facility along with the raw seawater. Impingement can occur when larger organisms become trapped against screens or grates by the force of the water flowing into an intake opening. The effect of impingement is often taken into consideration when assessing the environmental effects of large-scale intake systems such as major power plants. However, impingement is generally less of a concern for intakes on desalination facilities, as their relatively smaller scale provides ample opportunity to implement screening technologies such as wedgewire screen modules that essentially eliminate impingement risk.

A WateReuse Research Foundation report, titled "Development of Habitat Restoration Programs for the Mitigation of Impingement & Entrainment Effects from Intakes for Seawater Desalination Facilities" provides an overview on the use of restoration to compensate for the effects of ocean intakes and provides guidelines for the development of restoration projects to compensate for the effects of desalination plant intakes.

US history and policy

The assessment of impingement and entrainment effects has a long history in the United States due to the passage of the 1970s' Clean Water Act (CWA). Section 316(b) of the CWA required the US Environmental Protection Agency (EPA) to implement regulations that would reduce the environmental effects of cooling water intake systems for power plants and other industrial facilities. Subsequent guidance developed by the EPA, in relation to entrainment assessment, focused on larval fish and shellfish, prioritizing them as organisms at the greatest risk of being adversely affected by entrainment.

Habitat restoration to offset losses due to entrainment and many other development-related impacts to the marine environment also has a long historical precedent. It has been an integral part of policy and guidance in several policy areas. Section 404 of the CWA addresses the management of wetlands, the Natural Resource Damage Assessment process (applied under both the Oil Pollution Act and the Comprehensive Environmental Response, Compensation, and Liability Act), and the National Pollutant Discharge Elimination System permitting process established under the CWA all contain consideration of habitat restoration as compensatory mitigation for environmental losses.

The use of habitat restoration for mitigation of intake effects under Section 316(b) of the CWA was struck down during the lengthy litigation process over the last 20 years that restructured the regulations of this policy. None of these programs address intake issues associated with desalination project development directly, but their prominence in US environmental policy coupled with their extensive examination and development of implementation practices makes their examination critical to developing guidelines for a compensatory mitigation program to address intake system impacts for future desalination plant projects.

Mitigation planning process

Although each of these policy programs differs in several ways, some characteristics are universal. These universal characteristics form the basis of the guidelines described in the WateReuse Research Foundation report. In each case, these programs guide the compensatory mitigation planning process to consider three stages: the determination of impact, the determination of mitigation, and the implementation and management of the compensatory mitigation project.

Impact determination begins with an assessment of the losses of resources or habitat, and ends with a decision as to whether there is a need for compensatory mitigation. It is important that a quantitative approach be used to assess impacts because this will provide the necessary understanding of the type and magnitude of the impacts necessary for determining the need for mitigation. The impact determination also provides the basis for assessing the nexus to the impacts required when considering potential restoration projects during the second stage in the process, the determination of mitigation. The data from the impact assessment are also critical in scaling any compensatory mitigation projects. The compensatory mitigation implementation plan should clearly define the losses, the nexus between the losses and any proposed project, and the scaling approach used to determine the appropriate level of mitigation.

The determination of mitigation begins once the impact determination stage is complete. Establishing the mitigation goals is central to guiding this planning process. Setting mitigation goals is largely

Coastal wetland habitats are often candidates for compensatory habitat enhancement or restoration as mitigation for intake effects.
Photo by Tenera Environmental

The most rigorous approach developed to date is an assessment approach that looks at proportional, or relative, losses to a biological population.

determined by the policy context under which the compensatory mitigation program is being implemented. For example, under the CWA's Section 404, the stated policy position provided by the regulatory authorities (which are the EPA and the US Army Corps of Engineers) requires the restoration or enhancement of wetlands provide similar wetland functions and acreage to the wetlands that are lost. The Desalination Amendment to the California Ocean Plan provides a different level of mitigation goal. The policy states that mitigation "...is the replacement of all forms of marine life or habitat that is lost due to the construction and operation of a desalination facility" (§M2e, May 5th 2015 draft). The implication of this policy statement, in regards to setting the goals of a compensatory mitigation program, is that the marine organisms lost due to entrainment (which primarily includes larval, planktonic, and microscopic organisms) must be fully replaced through mitigation. For many planktonic species with little to no habitat association other than the pelagic ocean environment, it is highly unlikely that full replacement of these entrained organisms could be accomplished through habitat restoration since pelagic ocean habitat cannot be reliably created, restored, or enhanced.

The mitigation determination stage primarily involves the identification and selection of projects with potential for meeting the mitigation objectives. Evaluating and selecting compensatory mitigation projects is best performed against a matrix of criteria in order to provide a structured assessment that can be objectively considered by all stakeholder groups. While many potential criteria exist that could be used to evaluate compensatory mitigation projects, three broad categories encompass the key factors that should be considered for selection of a successful compensatory mitigation project. These categories are: the nexus to impact, the feasibility of a project, and obtaining stakeholder acceptance.

In order to provide documentation of, and a cohesive structure to, a compensatory restoration program, it is recommended that a formal implementation plan be developed early in the program planning process. The implementation plan should include a statement of goals, an explanation of roles and responsibilities, a targeted monitoring and implementation assessment program, and project timelines and allocated budgets.

In the early planning stages, a conceptual model of the restoration project should be included in the plan. As the project develops, the plan should be updated to include more detailed approaches to project implementation. It is expected that the development of a plan would be an ongoing process and would be conducted using an adaptive management approach. During planning, the adaptive management process should be influenced by regular review against the project objectives and ongoing findings (such as determination and characterization of impacts, identification of alternative restoration projects, etc.). As the compensatory mitigation project is implemented, adaptive management should be informed by a scientific monitoring program.

A further consideration in the implementation of the compensatory mitigation project is the assurance of long-term stewardship. This is to ensure the compensatory mitigation fully meets the goals of the project, which is likely to require development, maintenance, monitoring, and management over a period of several years to several decades, and ultimately until the end of the useful life of the desalination plant. Other policy frameworks that incorporate habitat restoration as mitigation may differ from that of a desalination intake specific policy framework with respect to long-term stewardship. For example, Section 404 of the CWA addresses the actual and permanent loss of wetland habitat and therefore the policy actively promotes self-sustaining restoration projects that will permanently replace such losses. However desalination plant intake effects are unlikely to cause permanent impacts beyond the operational life of the intake, therefore the consideration of long-term stewardship is likely to only extend to the point of desalination plant decommissioning.

Scaling, or equivalency analysis

Scaling – the process of estimating the acreage and costs associated with mitigation restoration – is fundamental to underpinning the nexus-to-impact of a compensatory mitigation project. The process should be transparent and objective in order to satisfy a diverse array of stakeholder concerns – and, therefore, should involve a quantitative method of scaling.

A variety of scaling approaches exist, although they are all united by the fundamental principle of equating losses with gains. As a consequence of the application of this principle across disparate policy and legislative programs that allow for or require compensatory mitigation, the developers of approaches to implementing compensatory mitigation scaling have devised different terminologies to describe the basic principles. The WateReuse Research Foundation report proposes to unify the terminology under the label "equivalency analysis." The process of equivalency analysis requires that losses be equated to gains in some manner.

The manner in which an equivalency analysis is conducted is important to the outcomes of the process. Planktonic larval organisms are usually produced in very large numbers relative to their adult equivalents. A single adult female California halibut (*Paralychthys californicus*), for example, is capable of spawning tens of millions of eggs per year. Absolute entrainment figures are of limited value without a context within which to understand them. An annual entrainment of 20 million California halibut larvae may sound like a substantial number unless some context is provided, such as the reproductive capacity of the fish or the size of the population. Therefore assessment methods have been developed that provide a context for decision makers to determine acceptable levels of impact, or to assist in the scaling of mitigation to offset the entrainment effects that are tangible and reflect the nature of the effect.

Assessing intake effects

The most rigorous approach developed to date is an assessment approach that looks at proportional, or relative, losses to a biological population. This approach is more robust to estimation error than an absolute measure of losses based on the numbers of larvae entrained, because entrainment losses will change considerably within and between years due to numerous physical and biological factors that affect levels of larval production and survival. In California, the empirical transport model (ETM) has been developed and successfully implemented for over three decades for assessing power plant intake cooling systems and has been incorporated by regulators into the Draft Desalination Amendment to the California Ocean Plan due to be adopted later this year. The ETM provides a relative measure of impact integrated across a year – called proportional mortality (PM) in the ETM terminology – that should vary much less over time than absolute estimates of impact (such as an estimate of total entrained fishes). Similarly, the area of production foregone (APF) method has been identified as the preferred approach for scaling mitigation losses identified from the ETM assessment. The APF estimate resulting from ETM for an individual species should also be relatively invariant over time, because while the larval production from an area of habitat within the area of source water potentially subject to entrainment (known as the source water body) will vary considerably over time, the proportion of the larvae in the source water produced by that area of habitat should be much less variable.

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It is important to recognize that the results from an ETM should be considered separately from APF. Although the output from ETM has been criticized as potentially lacking an immediately intuitive currency for impact assessment, the ETM estimate of PM should be the fundamental basis for any assessment of the environmental impact of entrainment effects. Assessing the environmental impact of entrainment effects is a necessary step in order to determine whether there is a need for compensatory mitigation. The ETM is a robust method for providing this assessment because the PM estimates it provides are the same type of information used by resource scientists in managing fisheries. The estimates of PM are similar to estimates of the effects of fishing mortality on a population, and in this context can be interpreted relative to other sources of mortality.

Another important consideration that only applies to the assessment of impact using the ETM's PM estimate is that the mortality is occurring to the larval stock in the source water body and not an adult population. Interpreted in this context, an estimate of PM that is very low relative to other natural sources of mortality, or levels of natural variation, indicates that entrainment effects on that organism are not likely to be significant.

In contrast to PM, the actual effects of entrainment can be distorted if they are evaluated using APF. Even though the ETM estimates of PM may be very small, the resulting APF estimate may represent a large area, resulting in the impression that entrainment has a large impact on the population. For example, if the source water body for the species with a PM of 1 percent extended over a coastal area of 100 square km (which is representative of many species from studies along the California coast), the resulting APF would equal 100 hectares, which is a large area of habitat. The likelihood that the proportional loss to the larvae would affect the population is unknown when APF alone is considered.

The success and widespread use of APF for scaling restoration projects will require that a consistent approach to its use be adopted, and especially that a method be developed for scaling larval production in open coastal waters into other coastal habitats. Although the APF in this case would result in habitat area that is not equivalent to open coastal waters, the use of out-of-kind mitigation is usually acceptable when it results in creation of habitat with greater ecological value.

Solution for coastal desalination

Compensatory mitigation for environmental effects is an established field in many other areas of environmental development planning. Habitat restoration as compensatory mitigation for the effects of desalination plant intakes in coastal and estuarine environments is a viable solution to addressing the sustainable implementation of large-scale coastal desalination.

Implementation should include early consideration of the identification of goals and objectives as well as the incorporation of stakeholder issues, and these considerations should continue throughout the process. Objective scaling requires a quantitative approach, and relative approaches such as the ETM with APF are likely to be the most robust scaling methods to apply to desalination plant intake effects because of the highly variable nature of marine populations, particularly planktonic populations subject to entrainment effects. As with all project planning activities, early consideration of environmental factors will ensure that implementation progresses smoothly and will increase the likelihood of success.

Authors' Note

John Steinbeck and Joe Phelan are with the US-based environmental consulting firm Tenera Environmental located in Lafayette and San Luis Obispo, California. John Steinbeck is the Tenera vice president and principal scientist, and Dr. Phelan is a senior scientist with the company.