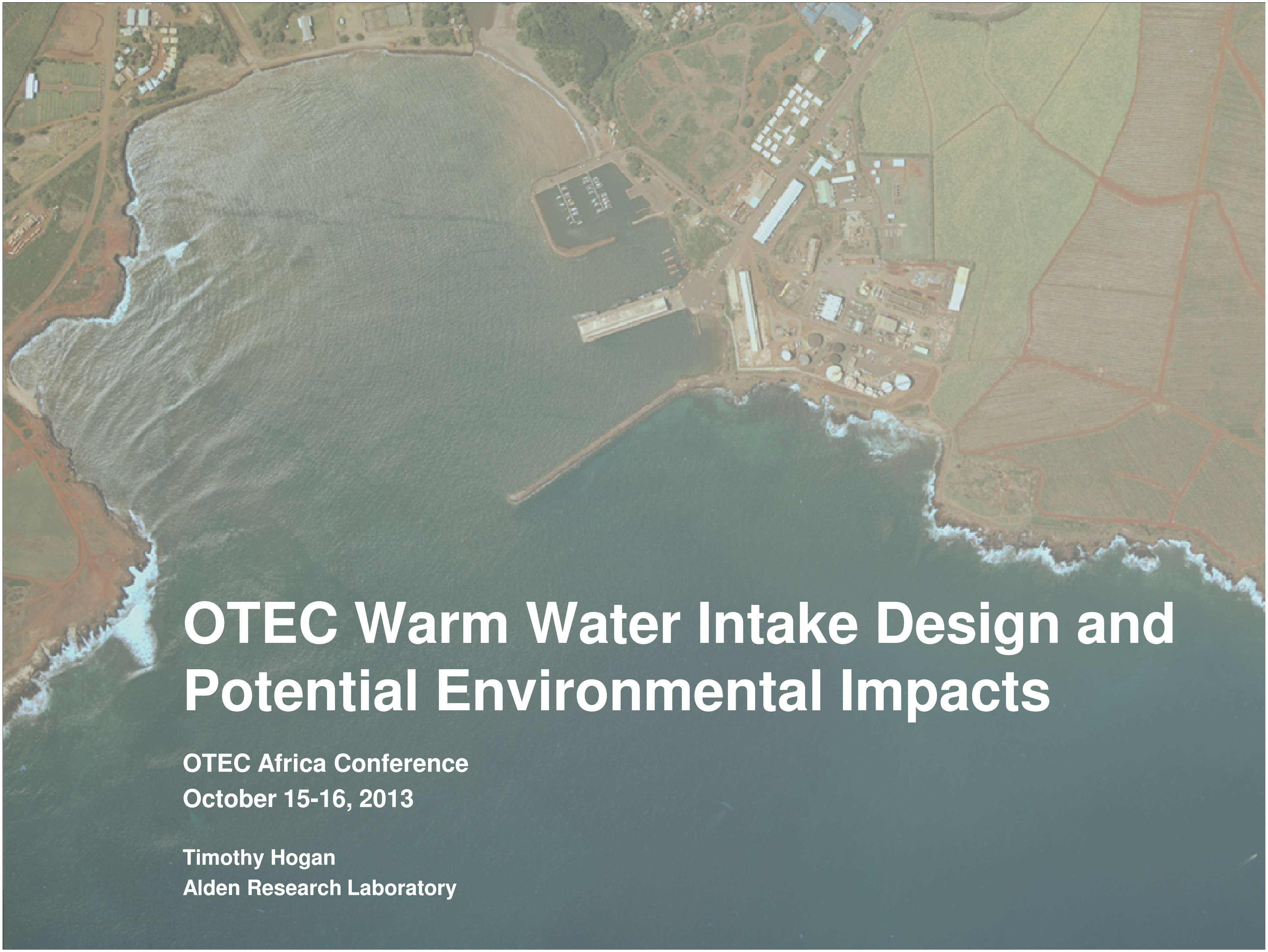


# OTEC Warm Water Intake Design and Potential Environmental Impacts

OTEC Africa Conference
October 15-16, 2013

Timothy Hogan
Alden Research Laboratory

# Outline

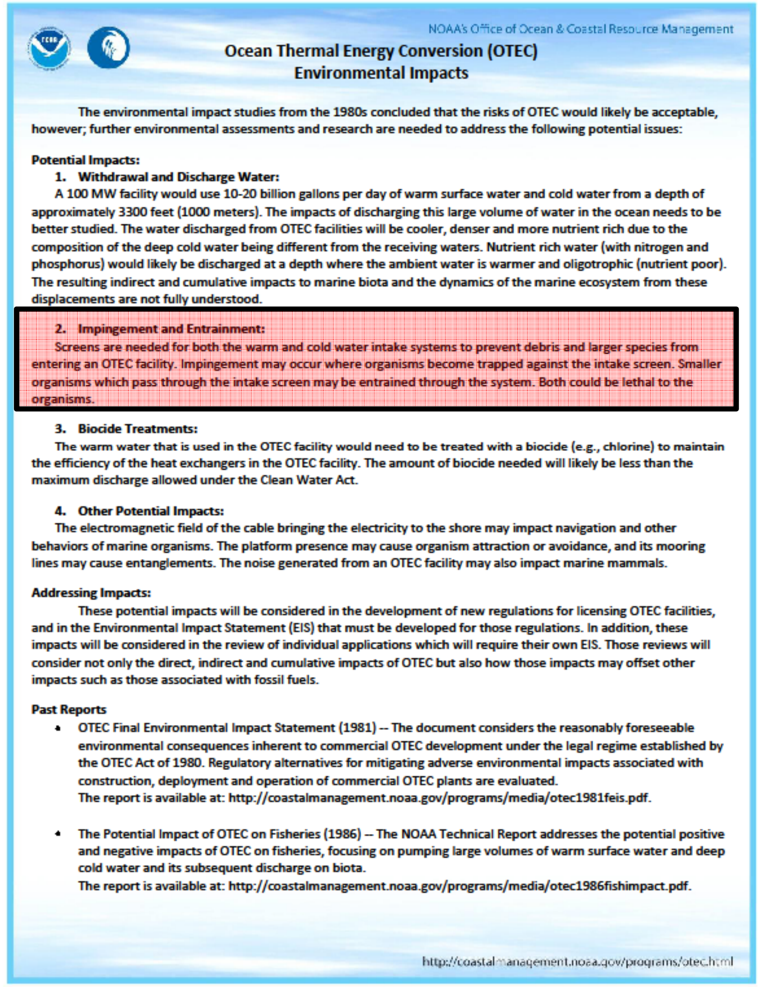
- Introduction
  - Barriers to OTEC commercialization
  - Impingement and entrainment
  - Intake regulation in the U.S.
- Research objectives
- Intake design
- Potential fisheries impacts
- Results
- Conclusions

# Introduction

# Introduction

## Barriers to Commercialization

- Environmental
  - Intakes (mainly warm water)
  - Discharge
  - Regulatory framework
- Technological
  - Cold water pipe
- Economic
  - Ancillary civil structures
  - Project financing



NOAA's Office of Ocean & Coastal Resource Management

**Ocean Thermal Energy Conversion (OTEC)**
**Environmental Impacts**

The environmental impact studies from the 1980s concluded that the risks of OTEC would likely be acceptable, however; further environmental assessments and research are needed to address the following potential issues:

**Potential Impacts:**

1. **Withdrawal and Discharge Water:**
A 100 MW facility would use 10-20 billion gallons per day of warm surface water and cold water from a depth of approximately 3300 feet (1000 meters). The impacts of discharging this large volume of water in the ocean needs to be better studied. The water discharged from OTEC facilities will be cooler, denser and more nutrient rich due to the composition of the deep cold water being different from the receiving waters. Nutrient rich water (with nitrogen and phosphorus) would likely be discharged at a depth where the ambient water is warmer and oligotrophic (nutrient poor). The resulting indirect and cumulative impacts to marine biota and the dynamics of the marine ecosystem from these displacements are not fully understood.

2. **Impingement and Entrainment:**
Screens are needed for both the warm and cold water intake systems to prevent debris and larger species from entering an OTEC facility. Impingement may occur where organisms become trapped against the intake screen. Smaller organisms which pass through the intake screen may be entrained through the system. Both could be lethal to the organisms.

3. **Biocide Treatments:**
The warm water that is used in the OTEC facility would need to be treated with a biocide (e.g., chlorine) to maintain the efficiency of the heat exchangers in the OTEC facility. The amount of biocide needed will likely be less than the maximum discharge allowed under the Clean Water Act.

4. **Other Potential Impacts:**
The electromagnetic field of the cable bringing the electricity to the shore may impact navigation and other behaviors of marine organisms. The platform presence may cause organism attraction or avoidance, and its mooring lines may cause entanglements. The noise generated from an OTEC facility may also impact marine mammals.

**Addressing Impacts:**

These potential impacts will be considered in the development of new regulations for licensing OTEC facilities, and in the Environmental Impact Statement (EIS) that must be developed for those regulations. In addition, these impacts will be considered in the review of individual applications which will require their own EIS. Those reviews will consider not only the direct, indirect and cumulative impacts of OTEC but also how those impacts may offset other impacts such as those associated with fossil fuels.

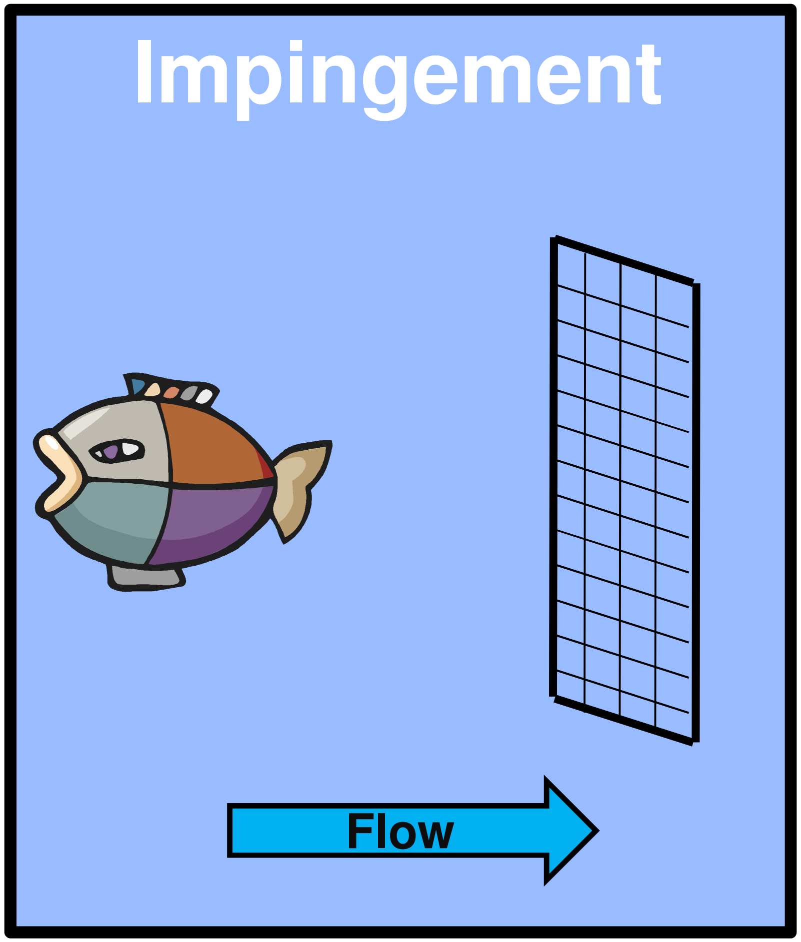
**Past Reports**

- OTEC Final Environmental Impact Statement (1981) -- The document considers the reasonably foreseeable environmental consequences inherent to commercial OTEC development under the legal regime established by the OTEC Act of 1980. Regulatory alternatives for mitigating adverse environmental impacts associated with construction, deployment and operation of commercial OTEC plants are evaluated.
The report is available at: http://coastalmanagement.noaa.gov/programs/media/otec1981feis.pdf.

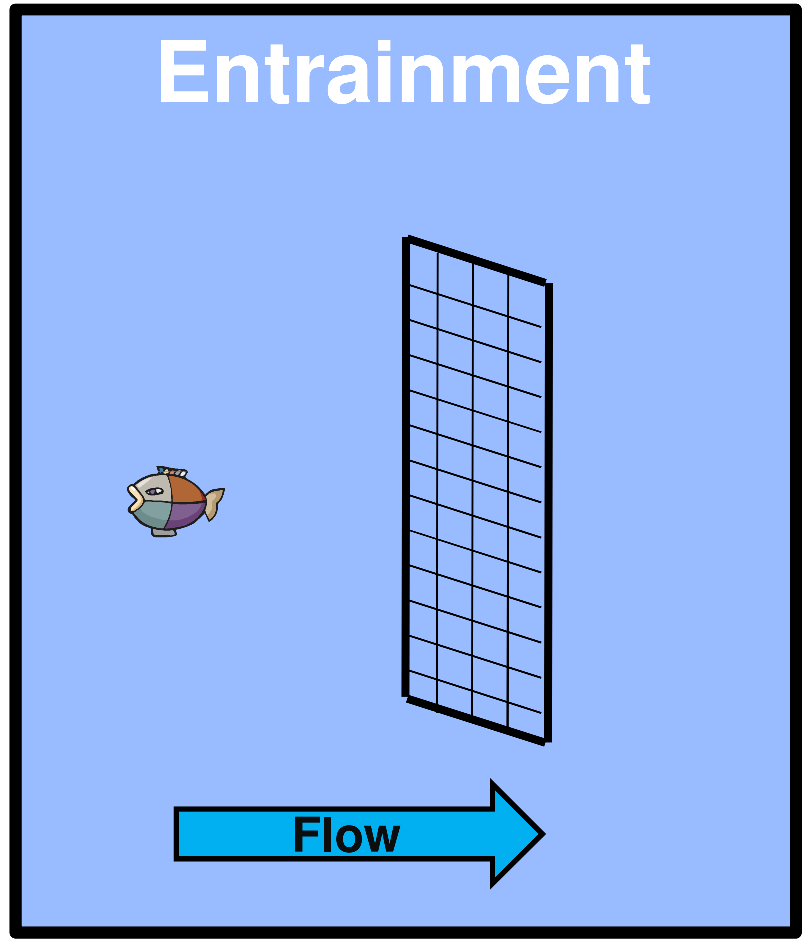
- The Potential Impact of OTEC on Fisheries (1986) -- The NOAA Technical Report addresses the potential positive and negative impacts of OTEC on fisheries, focusing on pumping large volumes of warm surface water and deep cold water and its subsequent discharge on biota.
The report is available at: http://coastalmanagement.noaa.gov/programs/media/otec1986fishimpact.pdf.

http://coastalmanagement.noaa.gov/programs/otec.html

# Introduction




Pinning of larger organisms on screen mesh




Passage of smaller organisms through screen mesh

# Introduction

## Intake Regulation in the U.S.

### Federal Regulation

**Clean Water Act Section 316(b)**

- For power plant intakes, but likely to be applied to OTEC
- Sets numerical performance standards

### State Regulation

- Multiple agencies involved
- Level of protection varies by state

*"…the location, design, construction and capacity of cooling water intake structures reflect the **best technology available for minimizing adverse environmental impact.**"*

*"…**trapped against screens** at the front of an intake structure."*

*"…**pulling large numbers of fish and shellfish or their eggs into** a power plant's or factory's cooling system."*

# Research Objectives

## Intake Design

- Evaluate warm water intake alternatives
- Select feasible warm water intake technologies for Kauai site
- Develop conceptual warm water intake designs

## Potential Impacts

- Conduct field sampling to:
  - characterize baseline populations of ichthyoplankton
  - determine which species may be susceptible to impingement and entrainment

ALDEN — Final Report, Award # DE-EE0002653 — August 2013

**The Potential Impacts of OTEC Intakes on Aquatic Organisms at an OTEC Site under Development on Kauai, HI**

FINAL REPORT

Submitted to:

U.S. Department of Energy
Golden Field Office
Award Number: DE-EE0002653

Submitted by:

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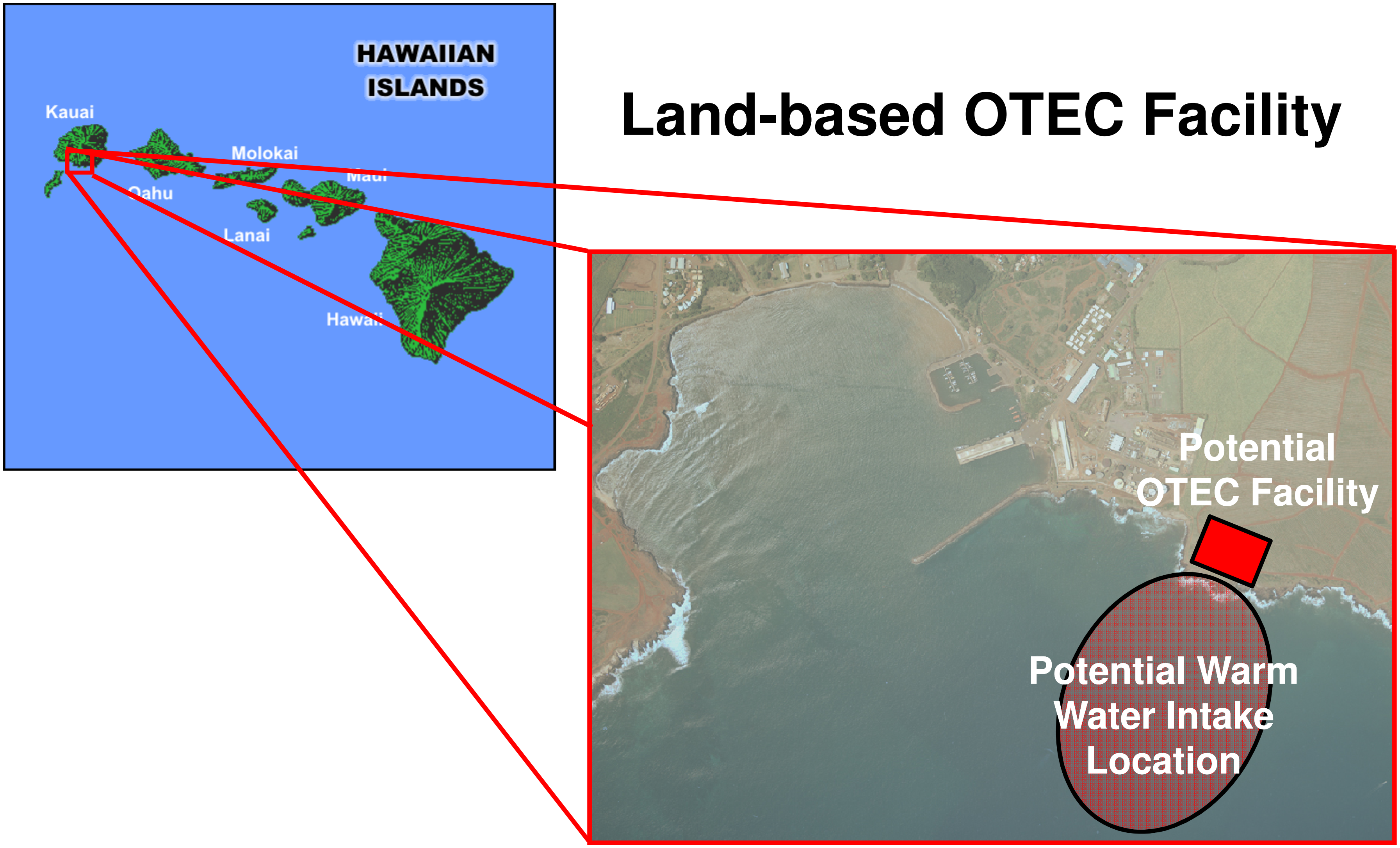
August, 2013

Report available at:
http://www.osti.gov/scitech/biblio/1092416

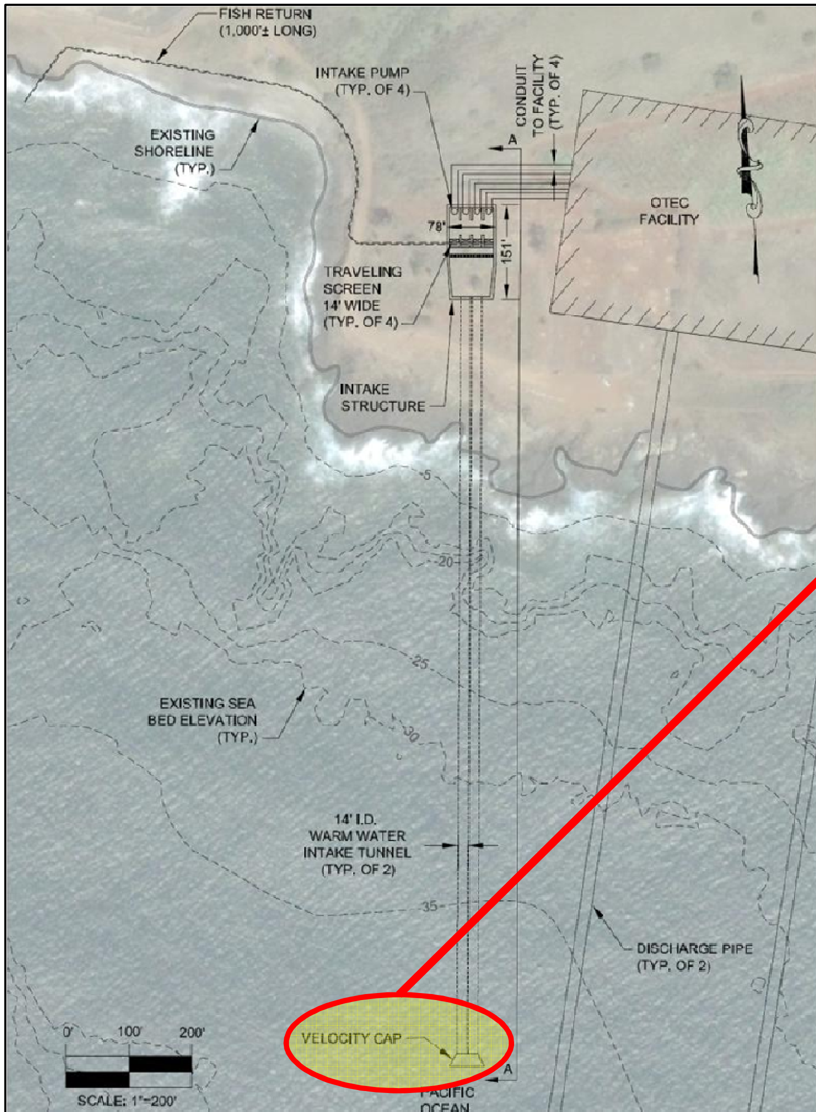
# Hawaiian Site – Port Allen, Kauai

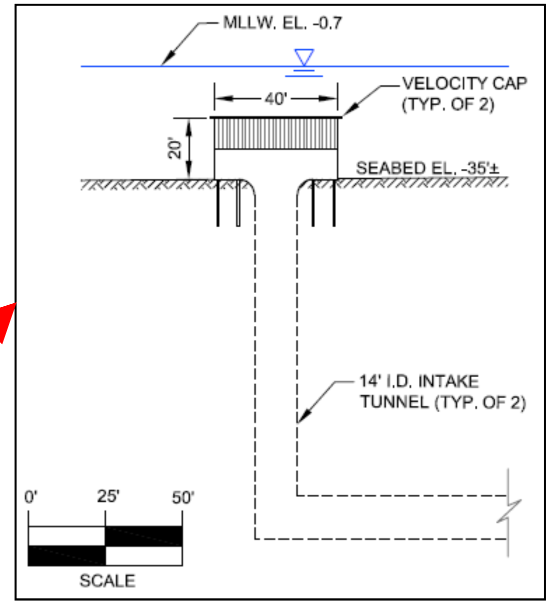
## Land-based OTEC Facility



# Warm Water Intake Design

# Offshore Intake/Onshore Screens

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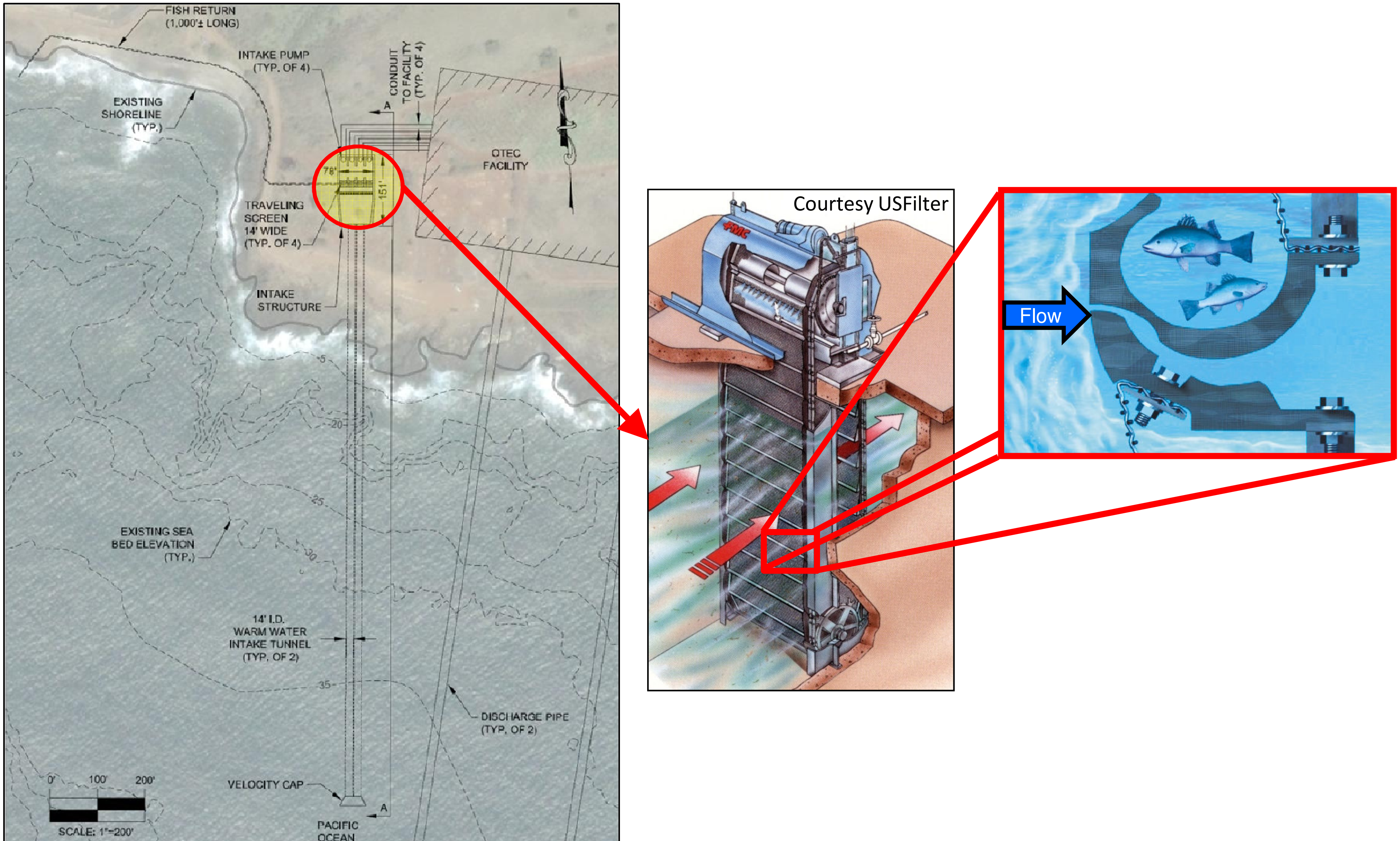

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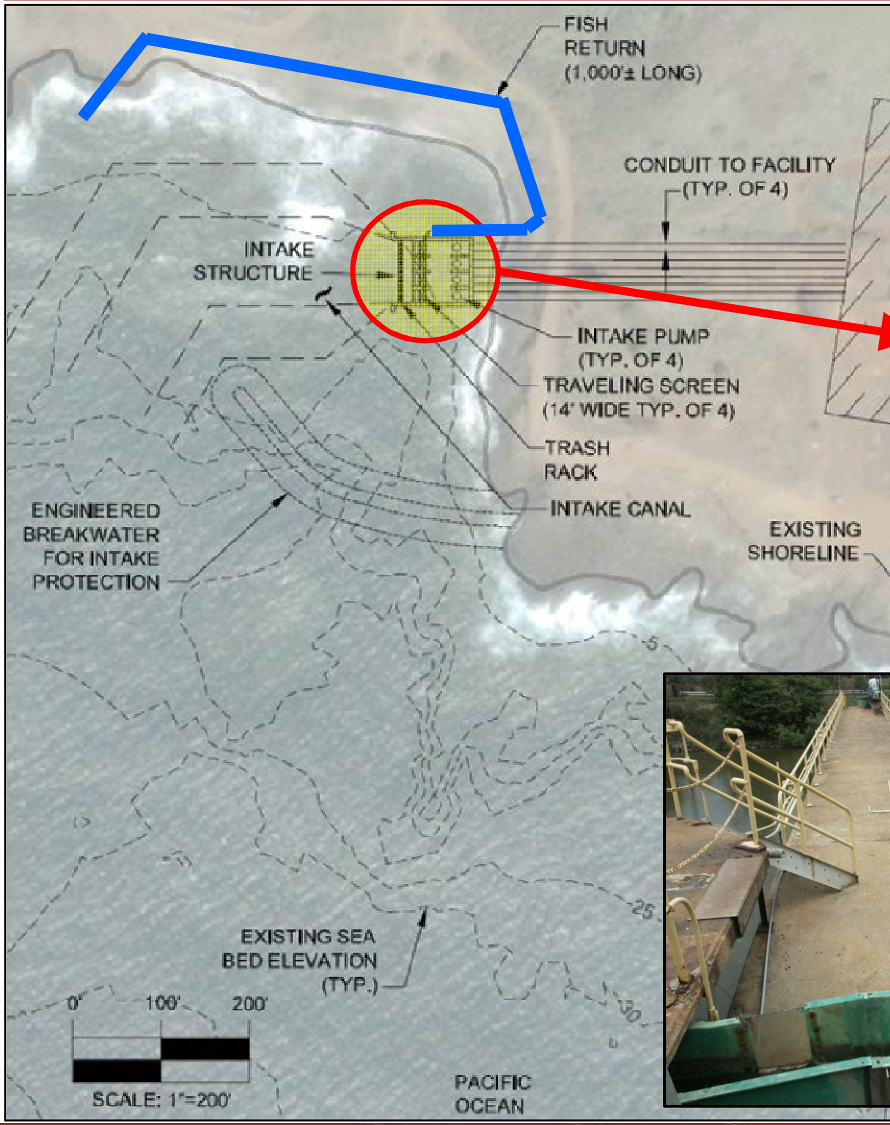
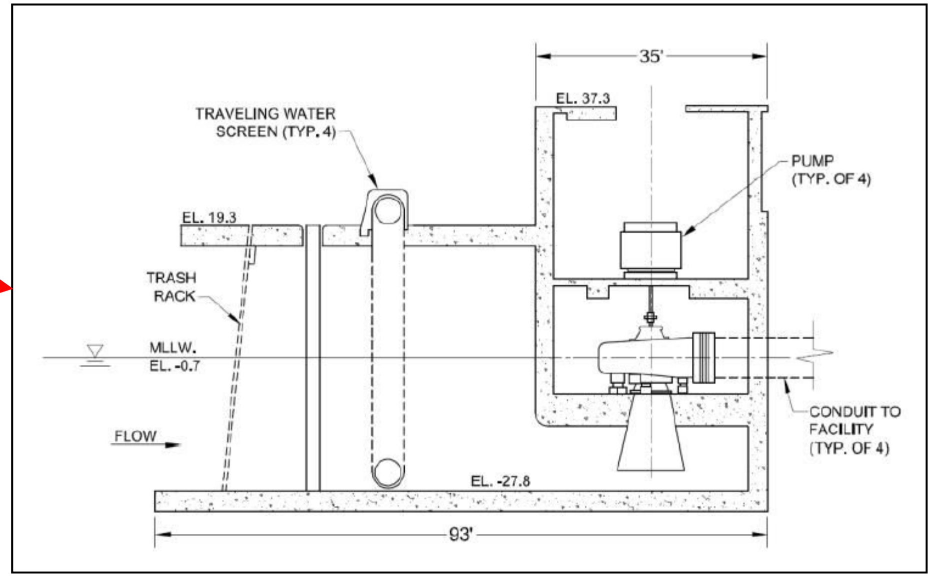
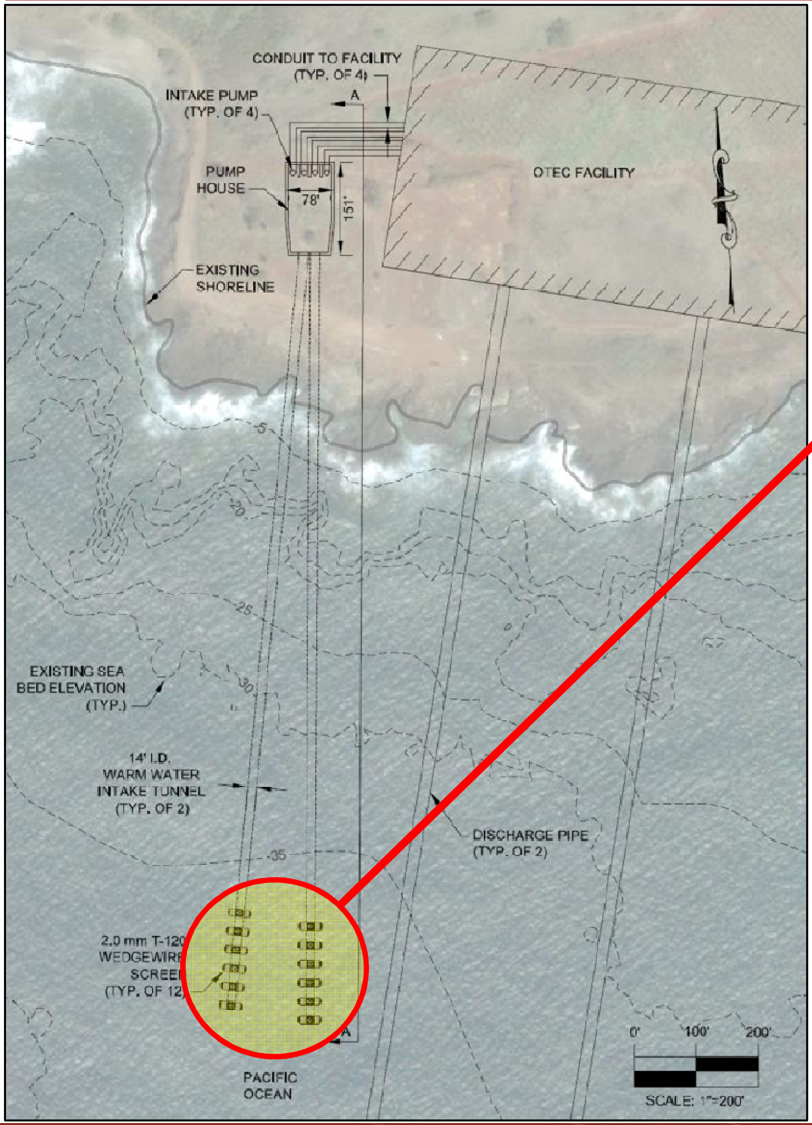
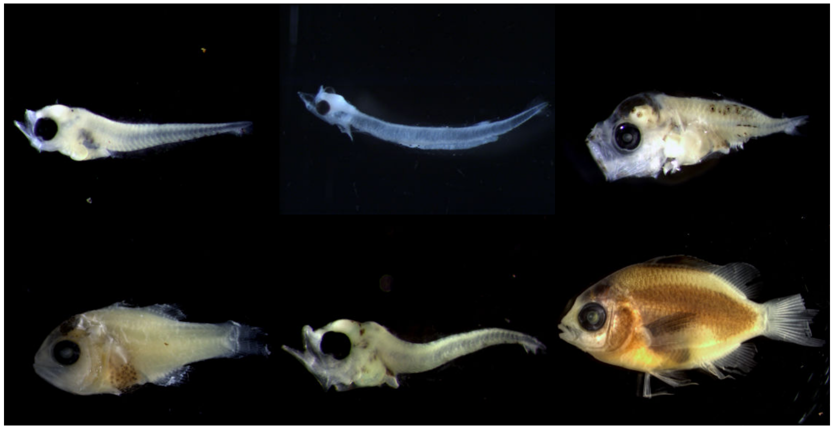



# Offshore Intake/Offshore Screens



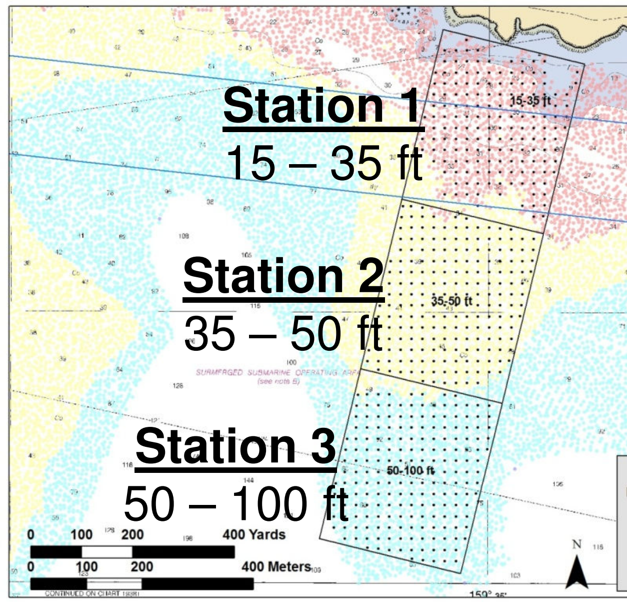



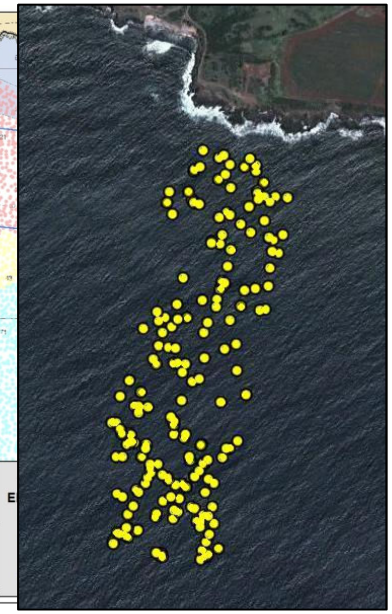
# Potential Impacts

# Field Sampling

## Objectives

- Characterize baseline populations of ichthyoplankton at intake location
- Document natural variations:
  - distance from shore
  - depth
  - diel period
  - season
- Determine species susceptible to impingement and entrainment

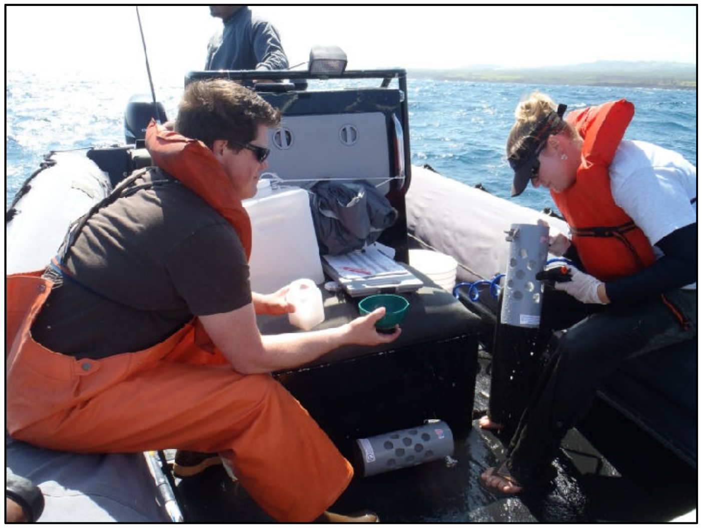


| Sample Station | Diel Periods | Depths | Replicates | Total Samples per Survey |
|---|---|---|---|---|
| 1 - Onshore | 2 | 1 | 3 | 6 |
| 2 - Middle | 2 | 1 | 3 | 6 |
| 3 - Offshore | 2 | 2 | 3 | 12 |
| | | | Samples/ month | 24 |
| | | | **9 months complete** | **205** |

# Methods

- Bongo net tows – 335-µm  mesh
- Samples preserved in 5% buffered formalin
- Samples sorted
- Organisms identified to lowest taxon possible
- Subset measured for length and head capsule



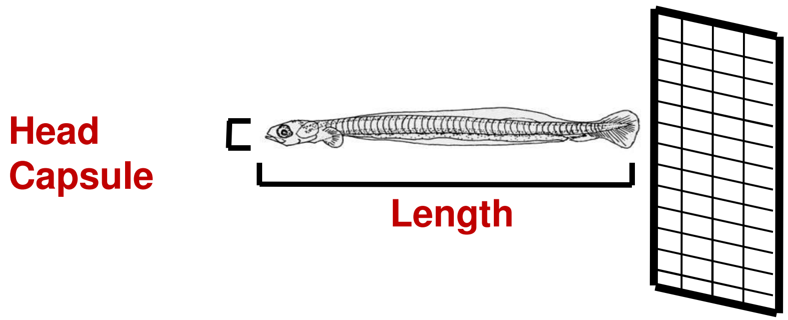
# Results

| Taxon | Common Name | Total No. | Average Concentration (No./1,000m³) | Percent of Total |
|---|---|---|---|---|
| **Fish Eggs** | Unidentified | 297,638 | 11,928 | 100% |
| **Fish Larvae** | | | | |
| *Schindleria* spp. | Infantfishes | 12,754 | 540 | 26.6% |
| Salariinae | Blennies | 7,969 | 335 | 15.9% |
| Gobiidae | Gobies | 5,758 | 243 | 11.5% |
| Pomacentridae | Damselfishes | 5,301 | 222 | 10.5% |
| *Enneapterygius atriceps* | Hawaiian triplefin | 4,148 | 180 | 8.5% |
| Myctophidae | Lanternfishes | 2,400 | 102 | 4.8% |
| *Encrasicholina spp.* | Anchovies | 2,251 | 99 | 4.5% |
| larval/post-larval fish | Larval fishes | 1,702 | 70 | 3.3% |
| *Cyclothone spp.* | Bristlemouths | 1,160 | 48 | 2.3% |
| Carangidae | Jacks | 805 | 34 | 1.6% |
| *Pristiapogon spp.* | Cardinalfishes | 747 | 31 | 1.5% |
| *Apogon spp.* | Cardinalfishes | 474 | 20 | 0.9% |

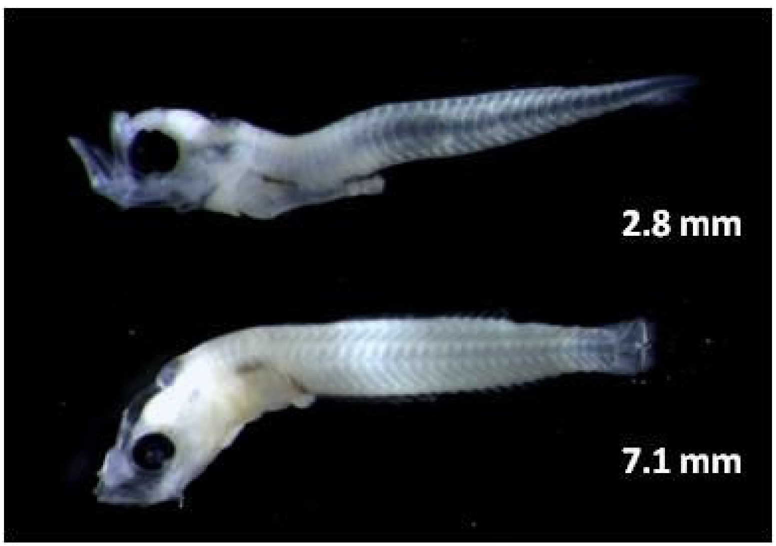
# Results

| Taxon | Common Name | Average Concentration (No./1,000m$^3$) | | |
|---|---|---|---|---|
| | | Station 1 | Station 2 | Station 3 |
| **Fish Eggs** | Unidentified | 12,602 | 11,495 | 11,362 |
| **Fish Larvae** | | | | |
| *Schindleria* spp. | Infantfishes | 577 | 689 | 503 |
| Salariinae | Blennies | 516 | 356 | 228 |
| Gobiidae | Gobies | 200 | 341 | 224 |
| Pomacentridae | Damselfishes | 214 | 275 | 191 |
| *Enneapterygius atriceps* | Hawaiian triplefin | 562 | 77 | 52 |
| Myctophidae | Lanternfishes | 84 | 81 | 124 |
| *Encrasicholina spp.* | Anchovies | 27 | 90 | 124 |
| larval/post-larval fish | Larval fishes | 48 | 79 | 71 |
| *Cyclothone spp.* | Bristlemouths | 31 | 43 | 50 |
| Carangidae | Jacks | 12 | 55 | 34 |
| *Pristiapogon spp.* | Cardinalfishes | 35 | 39 | 28 |
| *Apogon spp.* | Cardinalfishes | 37 | 20 | 12 |
| **Total larvae** | | **2,491** | **2,320** | **1,862** |

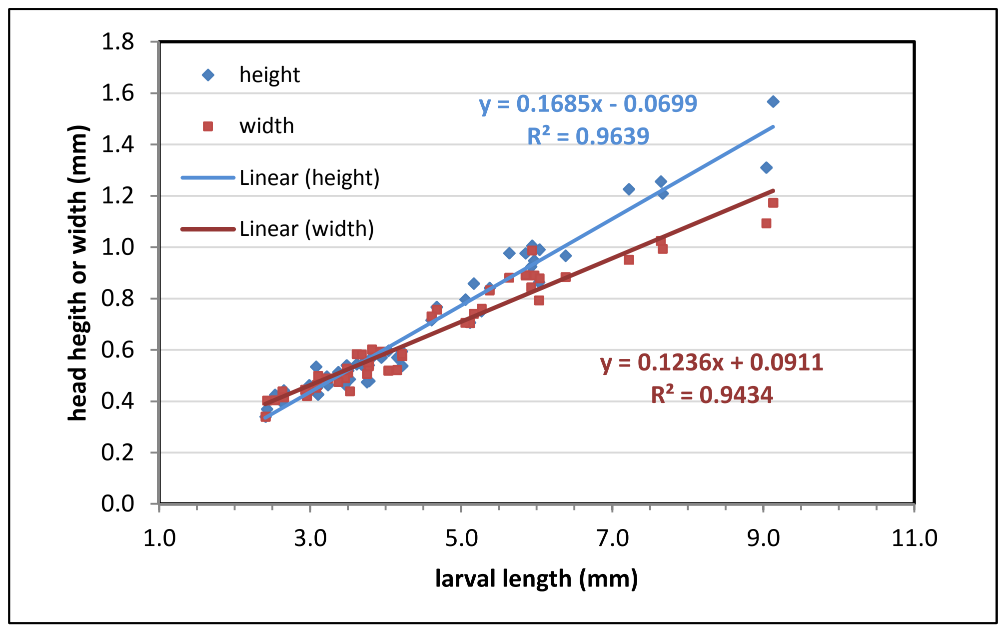
# Results



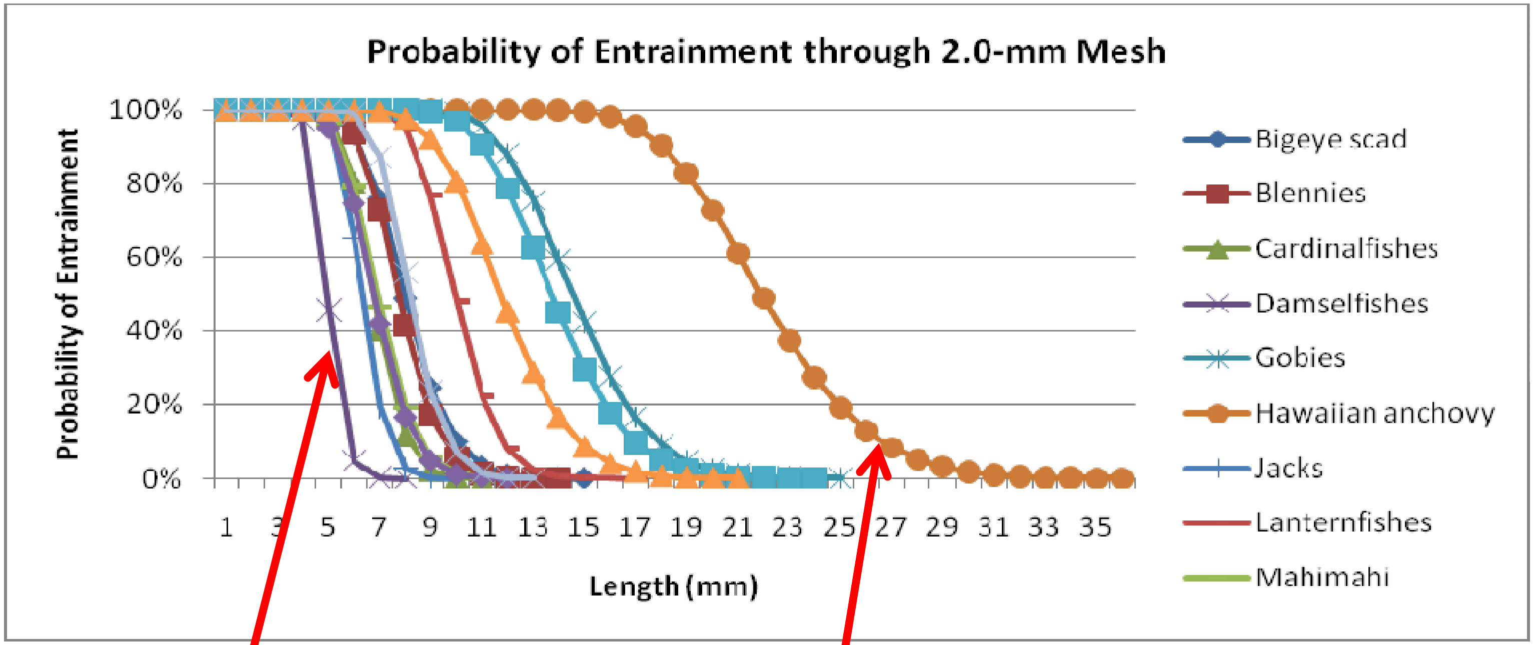

**Hawaiian triplefin,**
***Enneapterygius atriceps***

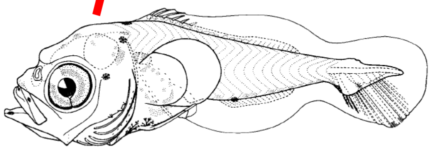


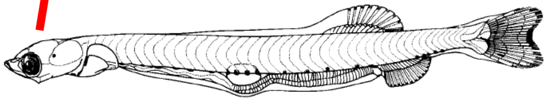

**Larval length versus head capsule measurements for Hawaiian triplefin**



# Results


Probability of Entrainment through 2.0-mm Mesh
Probability of Entrainment
100%
80%
60%
40%
20%
0%
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
Length (mm)
Bigeye scad
Blennies
Cardinalfishes
Damselfishes
Gobies
Hawaiian anchovy
Jacks
Lanternfishes
Mahimahi





# Conclusions

- Samples were dominated by larvae that become small nearshore adults, ~75%
- Few commercially- or recreationally-important species, <7%
- Dominant taxa are benthic spawners (eggs less susceptible to entrainment)
- Spatial variation:
  - By distance from shore – no diff for eggs, but lower conc of larvae offshore
  - By depth – no diff for eggs or larvae
- Temporal variation:
  - Higher conc at night for eggs and larvae
  - Spring peak for eggs
  - Late summer peak for larvae

# Implications for OTEC

- Offshore intake location may pose less of an entrainment risk than onshore
- No conclusive evidence of depth differences at depths sampled
- Construction of offshore intake pipeline would be more expensive and impactful to benthos than onshore
- Morphometric data can be used to optimize screen mesh sizes for intake
- Intake selected will have to balance environmental impacts with economic and operational feasibility

# Acknowledgements


## Funding provided by:

U.S. DEPARTMENT OF ENERGY

## Project Team:

**ALDEN Research Laboratory, Inc.**

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OCEES Ocean Engineering & Energy Systems

OCEAN THERMAL ENERGY CORPORATION

TENERA Environmental

AECOS, Inc.

# Questions?

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