<u>INVASIVE FISH CONTROL AND ERADICATION:</u>
A PRELIMINARY PLAN FOR THE
KAWAIELE BIRD SANCTUARY,
MĀNĀ PLAIN CONSERVATION AREA,
KAUA'I, HAWAI'I

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Executive Summary

The Kawaiele site is an important feeding and nesting area for endemic and endangered water bird species, including the Hawaiian stilt (*Himantopus mexicanus knudseni*), the Hawaiian moorhen (*Gallinula chloropus sanvicensis*) and the Hawaiian duck (*Anas wyvilliana*). These birds' populations depend directly and indirectly on the abundance of aquatic vegetation in the site, such as *Ruppia* sp.. Preliminary results from an ongoing research project have shown that the presence of invasive fish, specifically tilapia species, is hindering the growth of aquatic vegetation. Tilapia species are known to be voracious grazers, aggressive competitors and highly invasive. The records of negative impacts of introduced tilapia around the world and in Hawaii are staggering and irrefutable.

The objective of this report is to identify and analyze methods that could be used to control invasive fish in the Kawaiele site once the base reconfiguration phase is completed. The base reconfiguration involves the construction of sand berms that will create individual ponds, altering the topography and water chemistry of the site. While this report includes consideration of these changes, the applicability and efficiency of some methods cannot be fully appreciated at this point; these methods must be reevaluated accordingly.

Six fish control methods have been reviewed: Dewatering, netting/ trapping, electrofishing, blasting/ explosives, biocontrol and piscicides. For this end, we assessed technical literature and reports of experimental applications of each method and identified the advantages and disadvantages of the alternatives considering the characteristics of the Kawaiele site and the target species. We also looked at the possibility of integrating the methods evaluated in order to increase overall efficiency.

Dewatering was considered to be cost-prohibitive and unfeasible for this project. Electrofishing and blasting were identified as alternatives that may become feasible, depending on the morphological and chemical changes that are expected to occur after the base reconfiguration phase is completed. Netting and trapping were recognized as valuable adjunct methods that should be combined with chemical treatment, but that alone are not expected to be efficient. Biocontrol was identified as a possible post-treatment strategy to keep any surviving invasive fish at check, and prevent new invasions due to re-introductions, but is dependent on the identification of native fish that would prey on tilapia and careful scrutiny of potential undesired outcomes. Chemical treatment with rotenone has been identified as the most promising alternative to control tilapia in the Kawaiele. This is the only method available at this time that could kill most of the invasive fish populations, with low or no significant side effects, provided that the risk of contamination of groundwater and adjacent aquatic systems is proven to be minimal. To address this issue, we propose that dye tracing experiments and modeling of chemical dispersal are carried out to quantify risk of offsite contamination by rotenone. In addition, the use of chemical methods such as rotenone may face strong public opposition, which will require educational programs to clarify the real risks associated to the use of rotenone. Stakeholders' approval of the project and specific permits and licenses must be attained.

Finally, once the base reconfiguration has been completed, a pilot project should be carried out in order to test the assumptions made in this plan, quantify risks and evaluate the importance of seasonal variations in water levels, water quality and bird behavior to control methods' efficiency.

Background

The Mānā Coastal Plain is a low-laying flat area located in the west side of the island of Kauai, HI (Latitude: 22.02, Longitude:-159.77). Historically, the Mānā Plain provided nearly 1,700 ac of permanent, semi-permanent, and seasonal wetland habitats and was once the largest wetland area in the Hawaiian Islands. However, in 1923 the plain was drained and converted into agricultural land, mainly for the production of sugar cane, leaving only 200 ac of aquatic habitat comprised mostly of reservoirs and ditches. Prior to draining, the Mānā Plain may have had the highest densities of Hawaiian Duck and Hawaiian Coot (*Fulica alai*) in the archipelago (Ducks Unlimited Inc. 2005).

A consortium of partners is working to restore wetland habitat at the Mānā Plain. Partners involved with the preservation and restoration of Mānā Plain include: the State of Hawaii DLNR Division of Forestry and Wildlife, State of Hawaii DLNR Division of Aquatic Resources, U.S. Fish and Wildlife Service, USDA Natural Resources Conservation Service, University of Hawaii, National Park Service-Rivers, Trails, and Conservation Assistance Program, non-profit organizations, and local corporations.

Restoration of native ecosystems on the Mānā Plain is expected to benefit various endangered and endemic waterbird species including the Hawaiian stilt (*Himantopus mexicanus knudseni*), the Hawaiian moorhen (*Gallinula chloropus sanvicensis*) and the Hawaiian duck (*Anas wyvilliana*). In addition, the restoration of Mānā Plain will increase biodiversity, provide educational opportunities and economic benefits for local communities, and preserve cultural resources (Henry & Ryder 2008).

In total, this project aims to restore and enhance 105 ac of wetlands and coastal habitats. Phase I of this project intends to enhance the Kawaiele site, one of the scarce submerged habitats that exist in the Mānā Plain. Although not natural in origin, the Kawaiele site became a proxy for the natural aquatic habitats lost due to the drainage of the Mānā Coastal Plain. Unfortunately, later in the 1990's, invasive fish, including tilapias (various species) and mosquito fish (*Gambusia affinis*), were introduced into the waters of the Kawaiele site, causing substantial alterations to the fauna and flora that ultimately supports waterfowl populations (Ducks Unlimited Inc. 2005).

Preliminary results from a study that has been carried out since 2007, by Kim Peyton from the Botanic Department of UH Manoa in association with FWS, have shown that herbivorous invasive fish occurring in the Kawaiele site have significantly reduced native aquatic vegetation such as *Ruppia* sp., a seagrass that is essential for the subsistence of the birds in coastal wetlands. *Ruppia* sp. is an important component of coastal wetlands and food source for coots (*Fulica* sp.) and waterfowl worldwide. The experiment carried out by Peyton and collaborators consisted of establishing 24 plots (1.5 m X 1.5 m) in randomly selected areas identified as suitable for growth of *Ruppia* sp.. Twelve of these plots were protected by fish exclosures (Fig. 1); the other 12 were set as control and did not limit fish access.

Figure 1. Kim Peyton adjusting fish exclosures. (Photo: Joana Tavares, DAR)

Ruppia sp. was transplanted into half of these plots in October 2007. Subsequent observations of the plots (after 3, 5 and 8 months) revealed that *Ruppia* sp. thrived in the plots it had been transplanted to if invasive fish were excluded, but was completely absent in both the control plots and the non-transplanted plots (Fig. 2). Researchers also documented the occurrence of two species of filamentous green algae in the fish exclosures. These were not transplanted into the exclosures, which indicates that a local germination banks for green algae are also being suppressed by invasive fish (Henry et al. 2008).

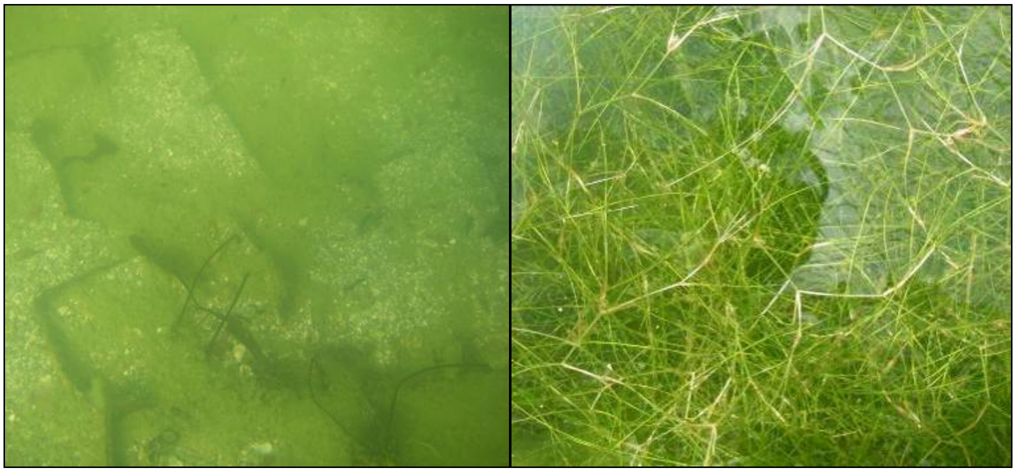

Figure 2. Preliminary results from experiments: On the left, bottom of control plot. On the right, *Ruppia* sp. thriving. (Photos by Adonia Henry, FWS).

These preliminary results indicate that 1) invasive fish are limiting the growth of wetland vegetation; 2) natural seed banks for *Ruppia* sp. are absent or not sufficient for natural germination, but if invasive fish are removed, transplanted seagrass will prosper and other beneficial vegetation and algae will develop.

Therefore, in order to reestablish desirable population levels for desirable vegetation, especially of seagrass coverage in the area and revitalize associated biota, it is crucial to eradicate the invasive fish or at least control the size of their populations.

The DAR, as a partner of the consortium for the restoration of the Kawaiele Wild Bird Sanctuary, has agreed to develop and oversee the invasive fish control plan in collaboration with the USFWS. Meetings to discuss fish control with consortium partners have been held since early 2008; the site was visited on June 9, 2008 and an initial draft of the Preliminary Control Plan for invasive fish was assembled on June 10, 2008 (Appendix 1). In that initial draft, a framework for the management of the invasive fish was laid out and a questionnaire was developed to identify the information necessary to characterize the treatment site and the target and non-target species. Here, we advance to Steps 3, 4 and 5 of the Preliminary Plan and identify possible treatment options to control invasive fish in the Kawaiele site.

KAWAIELE SITE DESCRIPTION

The Kawaiele site (Fig. 3) is located at the margin of HI-50 (Kaumualii Rd.), just south of the Barking Sands Missile Base and approximately 4 miles north from the town of Kekeaha. The Kawaiele site was created accidentally in the early 1990's, during sand mining operations that hit the groundwater table giving rise to the flooding of a 36 ac area. During subsequent years the Kawaiele served as nesting and feeding ground for the endemic and endangered aquatic bird species mentioned above. The site was proclaimed Wildlife Sanctuary by Governor's Executive Orders Nos. 3437 and 3685, and later officially incorporated into the Mānā Park Forest Reserve in 2007 (GEO Nos. 4207 and 4208).

Sources of Water and of Water Level Fluctuations

Ducks Unlimited, Inc. analyzed historical climate data from the Western Regional Climate Center for the Mānā Station by compiling monthly precipitation data from March 1949 through October 2000. They found that the average total monthly precipitation in the Mānā Plain during this period varied between 0.5 and 4 inches. The dry season in the area occurs between June and August (<1 in.) while the rainy season runs from October through March (>2 in.) with most rain falling from November through January (≥ 3 in.) (Henry & Palmer 2007).

Flooding of the entire plain is, therefore, a seasonal phenomenon but water levels on the Mānā Plain are kept artificially low by an extensive network of drainage ditches and pumps (Fig. 4) that are used to maintain agricultural lands sufficiently dry by exhausting water from the plain into the ocean. Although there is no direct superficial outflow of waters enclosed in the Kawaiele pits into the drainage ditches, the level of water in the Kawaiele site is influenced by the drainage system through the regulation of groundwater saturation.

Figure 3. Top: Satellite image of the Island of Kaua'i; red box indicates the location of the Kawaiele Site. Bottom: Satellite image of the Kawaiele site; yellow line indicates site area. (Images from Google Earth).

In addition, during periods of heavy rain, superficial flooding does occur, as it was observed in Dec. 2007, when water levels increased enough to cover 5 ft high exclosures (A. Henry, Pers. Comm.). In these instances, water from the Kawaiele site is expected to overflow and eventually flood into the drainage ditches and ultimately into the ocean.

Figure 4. Drainage pumps and ditches located at the Mana Plain. (Photo: Joana Tavares, DAR)

A much more permanent connection between the waters enclosed in the Kawaiele site and the ocean, however, is the subterranean one. The bottom sediment of the Kawaiele site is composed mostly by coarse to medium sands and the brackish nature of the water found in the pits is thought to result from the percolation of marine water into groundwater through and under the narrow (<1 mile) extension of land that separates the Kawaiele site and the beach. The extent of this connectivity, fluxes and contribution rates from the various sources of water for this site are not currently known.

Water Chemistry

Water chemistry data collected on Dec.3, 2007, Sept. 13, 2007 and Mar. 24, 2007[1] indicate that water temperature (T) can be quite high at the Kawaiele site, ranging from ~25.5 ºC in Dec. to 32 ºC in Sept.. Salinity (S) was also relatively high, ranging from ~8.5 ppt in Dec. to 12.2 ppt in Sept.. Water pH was slightly alkaline, ranging from 8.1 in Dec. to 8.6 in Mar.

[1] Source: Email from Greg Bruland to Thomas Kaiakapu reporting results from 2nd phase of EPA Wetland Program Development Grant project. Parameters were collected by the YSI hand-held sensor (salinity, pH, conductivity, dissolved oxygen, and temperature); nitrogen and phosphorus concentrations were analyzed at the Marine Sciences Analytical Lab at the University of Hawai‘i Hilo.

Water conductivity was relatively high, ranging from 14.7 ms/cm in Dec. and 20.6 ms/cm in Sep.. These data were collected in two different sampling sites, and showed small gradients among sites for all parameters in any of the three sampling occasions, except for T in Sep., which varied by almost 2 ºC from one collection site to the other. Turbidity was not measured in this survey. In another survey, DAR researchers collected water chemistry data in four different sampling locations inside our area of interest, in March 9, 2006 (Shimoda & Shakihara 2006). This survey registered T ranging from 24.8 ºC and 25.7 ºC (these values were slightly lower than the ones observed in Mar. 07); S ranging from 11.9 ppt to 12.1 ppt (higher than in Mar. 07); and pH ranging from 8.7 and 8.9 (similar to values measured in Mar. 07). Conductivity was not measured in this survey. Turbidity was measured in Nephelometric Turbidity Units (NTU) and was relatively low, ranging from 2 to 6.9.

Site Topography

A preliminary assessment of Kawaiele site topography (Fig. 4) indicates that the submerged area is overall shallow. Maximum depth of approximately 5 feet was recorded in seven distinct locations while most of the area is recorded to lie between 1 and 3 feet deep. Several small sand islands protrude the Kawaiele aquatic site. These can be several feet long and up to 4 feet high.

Topography mapping was carried out by Ducks Unlimited, Inc. using horizontal position average of four GPS observations with total duration of 23 hours over four separate sessions during the period between 02/08/06 and 02/26/06. These observations were submitted to NGS Opus Vertical for two fast static GPS observations of 45 min an 1 hour on separate days to monument NGS G1000 (OPID TU 686).

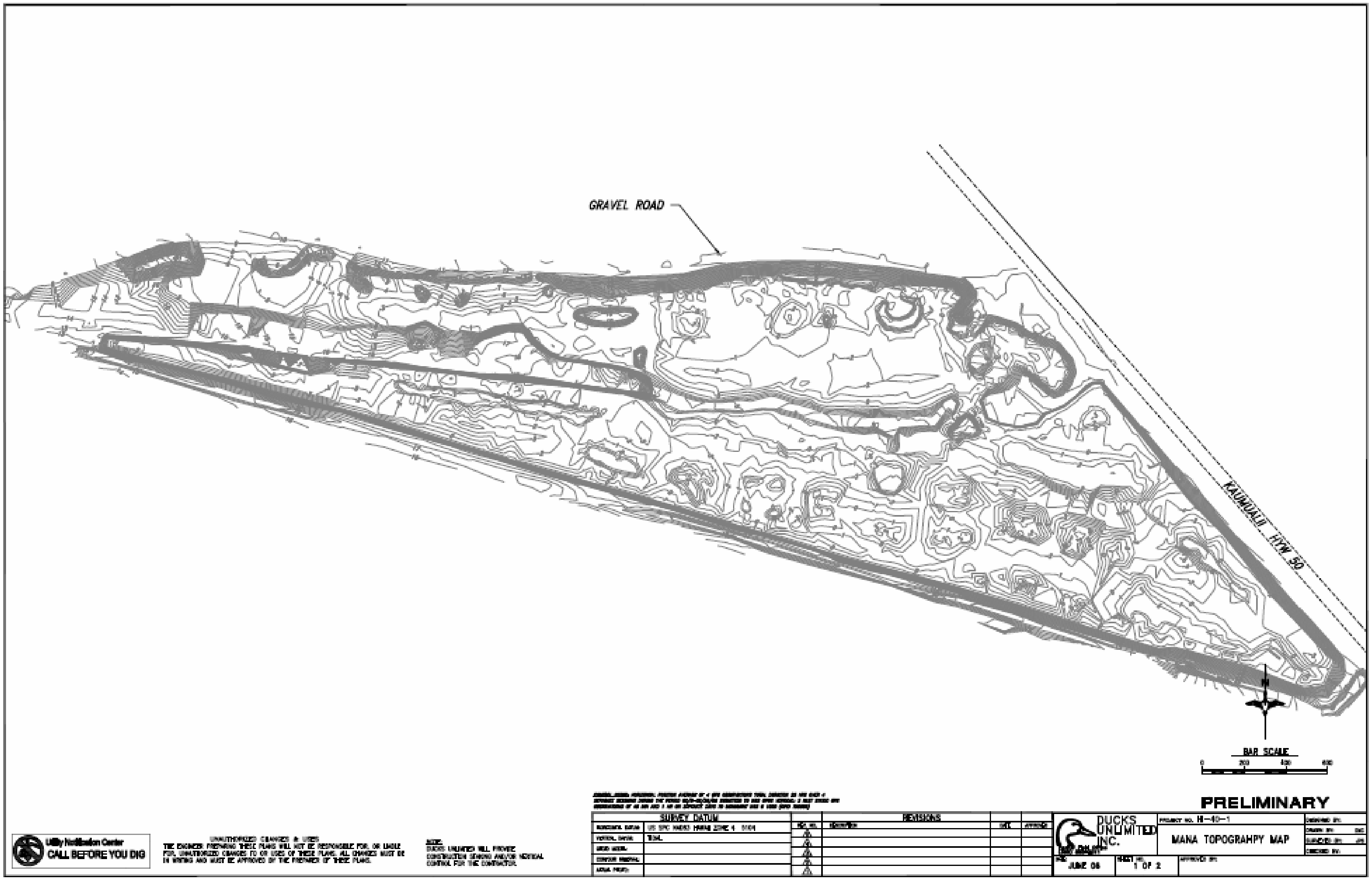

Figure 5. Topography map for the Kawaiele site. (Created by Ducks Unlimited, provided by Adonia Henry).

Aquatic Biota

Two fish surveys have been carried out in the Kawaiele site: one by researchers from the DAR, in April 2006 (Shimoda & Shakihara 2006) and another by researchers from USDA Forest Service, PSW, IPIF, in Mar., Sept. and Dec. 2007.

The first survey sampled in four different stations inside the Kawaiele pit using cast nets. This survey reported the occurrence of two species of tilapia, mozambique tilapia (*Oreochromis mossambicus*) and redbelly tilapia (*Tilapia zillii*), in addition to a hybrid, referred to as *Tilapia* spp.. Tilapia species were the most dominant fish captured (82.5% of total catch). The size of the adult tilapia was noticeably small and varied between 67 and 135 mm in total length.

Other fish identified in this survey were mosquito fish (*Gambusia affinis*), cuban mollies (*Limia vittata*), guppies (*Poecilia reticulate*), and liberty mollies (*Poecillia spp.*). This survey also recorded the occurrence of a Thiarid-snail identified as *Melanoides tuberculata*. Gastropods similar to the description of *M. tuberculata* were also observed in abundance in the bottom sediment of the Kawaiele site during a later visit by the DAR team (Fig. 6).

The USDA survey[2] reported the occurrence of only one species of tilapia, blackchin tilapia (*Sarotherodon melathorenon*) in addition to *Gambusia affinis*, and *Poecilia* spp.. However, no details of survey methods and efforts are available for this project. No native aquatic species was recorded in either survey. 14 jacks and one barracuda are known to have been resealed in the Kawaiele site, but have not been observed since their introduction. There are also reports of observation of at least one awa/ milkfish in the site as well as non-indigenous soft shell turtles and bullfrogs (W. Ishikawa and A. Henry, Pers. Comm..).

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[2] Source: Email from Rich MacKenzie to Thomas Kaiakapu (forwarded to me by Adonia) reporting results from EPA Wetland Program Development Grant project. Samples were collected in Dec., Sept., and Mar. , 2007.

Figure 6. Left: Bottom sediment from Kawaiele site. Right: close-up of gastropods

The common name 'tilapia' refers to a group of tropical freshwater fish in the family Cichlidae (*Oreochromis*, *Tilapia*, and *Sarotherodon* spp.) that are indigenous to Africa and the southwestern Middle East. Since the 1930s, tilapias have been intentionally dispersed worldwide for the biological control of aquatic weeds and insects, as baitfish for certain capture fisheries, for aquaria, and as a food fish. Tilapia can be found in lakes, wetlands, marine habitats, water courses, estuaries, and marine environments. They prefer tropical environments, but some species can tolerate cold temperatures down to 8 or 9 ºC. Sensitivity to salinity also varies greatly between species; some species can fully tolerate seawater (ISSG 2006).

Tilapias are highly prolific and tolerant to a range of environmental conditions and these characteristics provide these fishes superior capacity to adapt to new environments, outcompete native species and become highly invasive, causing serious deleterious impacts to entire ecosystems. Negative impacts of tilapia in various parts of the world (Canonico et al. 2005; Casal 2006; Costa-Pierce 2003; Courtenay 1997; Hogg 1976; McKaye et al. 1995; Vitule et al. 2009), and in Hawaii (Englund et al. 2000; SPREP 2000) are well documented in the literature.

The presence of tilapia in the Kawaiele site is conspicuous (Figs. 7 and 8). A common characteristic among various species of tilapia, including mouth brooders, is that the males excavate pits on the sand bottom to use as mating and spawning nests, as observed in all shallow areas the Kawaiele site (Fig. 7).

Figure 7. Tilapia mating/ spawning pits (Photo by Adonia Henry, FWS)

Figure 8. Tilapia specimen found at the margin of Kawaiele pit. (Photo by Brian Hauk)

In addition, a survey of aquatic insects was undertaken in March 2006. Two species of dragon flies (Odonata) were observed in the vicinities of the Kawaiele site: the introduced *Ischnura ramburii* and the dispersive indigenous *Panatal flavescens*. Neither are believed to breed near mixohaline waters, and therefore it was concluded that their presence near the Kawaiele site was occasional (Polhemus 2006).

Although scarce, at least two species of desirable wetland vegetation occur in the Kawaiele site: *Bolboschoenus maritimus* a perennial herb, which serves as shelter and food source for waterbirds and *Ruppia maritima,* which provides cover and food for many aquatic species (Henry & Ryder 2008).

Base Reconfiguration

As part of the Kawaiele site restoration project, sand berms are to be constructed in order to create approximately 16 isolated ponds as shown in Figure 9. The reconfiguration of the base will create smaller aquatic areas and consequently improve habitat for water birds.

Most of the material to be used in the construction of the berms will be excavated from the site itself, which will alter the current bathymetry of the site. Also, significant changes in the water chemistry are expected to take place due to the reconfiguration. For instance, some areas within the Kawaiele site have more permeable bottom than others thus, certain ponds are expected to different salinity gradients.

Detailed information on the future topography of the site is not yet available, but our estimates lead us to believe that ponds will range from 1.5 to 4 acres in area and depths may reach up to 7 feet in the deepest points of some ponds. Our approximations lead us to believe that volume of individual ponds will vary between 1.5 and approximately 11 acre feet, yielding between 60 and 70 acre feet (~20 million gallons) in combined total volume for the site.

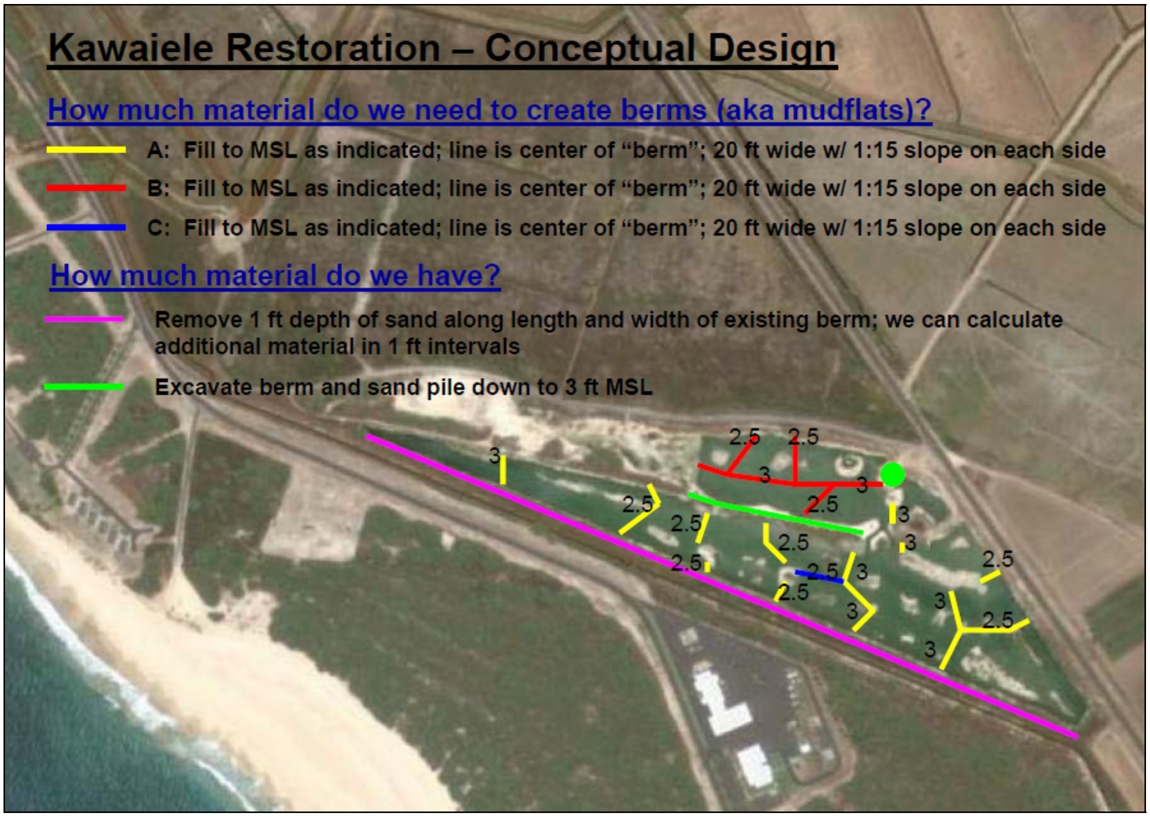

Figure 9. Conceptual design of Kawaiele base reconfiguration

ERADICATION AND CONTROL METHODS

The control and eradication of AIS pose a real challenge to environmental managers. In general, eradication of an established aquatic invader is very difficult at best, and more often impossible (Bax et al. 2001; Clearwater et al. 2008; Mack et al. 2000; Wittemberg & Cock 2005).

Here, we apply the terms eradication, control, and management to refer to distinct concepts. "Eradication" refers to all efforts aimed at completely eliminating an invasive species from a given system; "control" refers to all efforts aimed at maintaining an invasive species population under a predetermined size value within a given system; "management" refers to all actions and efforts related to the eradication, control and containment of an AIS as well as to actions related to the prevention of new introductions and re-introductions.

Fisheries managers rely on a variety of tools to control and eradicate undesirable fish populations, including chemical, physical and mechanical methods. These methods can be used alone or in combination in order to increase efficiency. Integrating pest management strategies allow managers to tie different control options to different areas, times, and life-history stages in an effort to minimize risks and costs while maximizing prospects for control success and protection from reinvasion.

Specifically, valuable methods to control invasive fish must 1) be effective against the AIS targeted while inflicting acceptable level of harm to non-target organisms (i.e. be selective), 2) be safe, affordable and easy to apply or implement, 3) stop acting within a reasonable limit of time (i.e. not be persistent), 4) be effective over a broad range of environmental conditions, 5) be registered for use in the aquatic environment, 6) be acceptable according to stakeholders' perception.

Thus, when choosing AIS control methods, managers must be able to access the best scientific information available about target and non-target species, the environment to be treated and the selected method(s) and consider the pros and cons in face of the particular characteristics of the project.

Next, we present five potential methods to control invasive fish in the Kawaiele site and a preliminary analysis of their applicability to this case in terms of the criteria mentioned above. Changes in the environmental conditions, accessibility to the site and obviously size and morphology of the water bodies will occur with the construction of the berms. While here we strive to anticipate how these changes will affect some criteria such as methods' cost, easiness if implementation and effectiveness, a review of this plan will be necessary after the berms have been put in place.

Method 1: Dewatering

The drainage of water bodies as a strategy to kill undesirable fish populations is a practice that is advantageous because it represents low risks to human health and usually inflicts limited long-term effects on the ecosystem. Also, it entails relative uncomplicated permitting process and neutral to positive public perception. On the other hand, dewatering is a nonselective practice, frequently expensive and difficult to implement.

The method consists of partial or total removal of water through the construction of drainage ditches or use of pumps. These techniques can be very costly and present various difficulties depending on the characteristics of the site and of the target species.

In the case of eradicating or controlling tilapia and mosquito fish in the Kawaiele site, dewatering the ponds does not seem to be a viable alternative mainly due to the geology of the area. The bottom sediment of the site is constituted mostly of sand and the main source of the water that floods into the pit is believed to be groundwater that permeates through the sediment and up. Thus, complete dewatering would be difficult, if possible at all.

Nevertheless, this method should be reconsidered after the new berms are raised and the ponds defined. Water levels in the site naturally decrease during the summer. Thus, after the smaller ponds are created, it is expected that water reduction may be more prominent in ponds where groundwater springs with less intensity and these ponds could be good candidates for additional dewatering efforts.

Dewatering the Kawaiele site is further complicated by the known resilience and high environmental adaptability of the target species. Although tilapia species are thought to be mostly freshwater fishes, some species of tilapia have been observed surviving in marine environments and coral reefs (REF, Randall 1987). Therefore, the use of drainage ditches and pumps to dewater the Kawaiele site is not an option due to the difficulty in stopping invasive fish from being flushed into the ocean and the consequent risk of facilitating a tilapia invasion on the adjacent marine environment. In addition, the effluents from the site would potentially pollute nearby aquatic systems with sediments and microorganisms. The feasibility of mounting the necessary filtering systems to avoid these types of contamination would be dependent upon the size of the candidate ponds, but costs of such operation are expected to be prohibitive.

Method 2: Netting and trapping

Nets and traps have been employed with various levels of success and in a variety of different settings to control and eradicate non-native fish (Meronek et al. 1996). Benefits of these physical removal methods include low impact on human health and general neutral to positive public acceptance. Also, the use of nets and traps usually do not impose long-term effects on the ecosystem. However, these approaches tend to be ineffective and cost-prohibitive in larger water bodies especially in the capture of the full range of sizes in a population. For instance, a mesh size appropriate for capturing adults may allow juveniles to escape, while using a smaller mesh size may be inefficient to capture larger individuals (gill nets) or yet clog the nets in a way that it becomes very difficult to haul them in. Selectivity of nets and traps will vary with fish size and behavior, but these methods are usually indiscriminate in nature and can also result in damage to valued species of fish. These negative impacts can be minimized by returning valued fish to the water, but this mitigation practice adds extra cost to an already expensive method.

Tilapia species are known to be especially hard to catch with nets, especially under invasive conditions. According to experts in aquaculture, when culture in ponds, tilapia are best harvested by seining and draining the pond. A complete harvest is not possible by seining alone. Tilapia are adept at escaping a seine by jumping over or burrowing under it. Only 25 to 40 percent of a *T. nilotica* population can be captured per seine haul in small ponds. Other tilapia species, such as *T. aurea,* are even more difficult to capture. A l-inch mesh seine (with bag) of proper length and width is suitable for harvest (Rakocy & McGinty 2005).

Attempts to capture tilapia at the Kawaiele site with nets were usually frustrated by these fish's capacity to jump over the nets, and sense minimal movements in the water which allow them to quickly bury in the bottom sediment and escape to deeper zones (A. Henry, FWS and W. Ishikawa, DAR, Pers.Comm.). Similarly, the efficiency of traps to capture these small tilapias is expected to be low. Nevertheless these alternatives should be reconsidered and tested after the base is reconfigured as it is possible that netting with fine meshed seine and/or gill nets could be combined with other methods (e.g. chemical) for successful tilapia elimination from small, shallow ponds.

It is difficult to estimate the costs of netting in the ponds that will be created after the base reconfiguration. We expect to need 3 feet of seine length for every 2 feet of pond width. Thus, for a 1 acre pond, approximately 100 feet of fine meshed (<2 inches) seine net may be required. For perspective purposes, a 4 feet high, 25 feet long seine net (2 in. mesh) costs about US$90 (Memphis Net &Twine, Feb. 2009). Personnel requirements will vary with pond size but we forecast it may exceed 50 individuals to handle the nets when netting in the larger ponds.

It is important to highlight that fishing gear characteristics are regulated by Hawaii's State Law (mainly by HAR 13-75). For instance, the use of nets with fine meshes (i.e.

<2 ¾ inch stretched mesh for lay nets; < 2 inch stretched mesh for seine nets) by anyone other than DLNR/ DAR personnel is prohibited. Thus, other agencies and parties must consult with the DAR to find out about special permits and exceptions that may apply to the use of nets and traps.

Method 3: Electrofishing

Electrofishing consists of using electric fields in water to stun fish and, by doing so, to facilitate their capture. This method is commonly applied for surveying purposes to sample fish populations and determine abundance, density, and species composition.

Electrofishing has been a valuable sampling technique in North America for over half a century, but there has been increasing concern among fishery biologists and managers regarding its potential for harming fish. While electrofishing normally does not kill fish, which apparently return to their natural state shortly after being stunned, mortality can occur and recent evidence indicates that the practice can cause substantial injury to the spinal column and associated tissues of fish that survived pulsed direct current. Electrical-field factors considered in the literature to affect the incidence of electrofishing-induced mortality and spinal injuries (including associated hemorrhages) include type of current, intensity, duration, orientation (relative to the fish), and for AC and PDC, waveform characteristic such as pulse or wave frequency, shape, and width. Related biological factors of concern include species, size, and condition (Snyder 2003).

There are three basic types of electrofishing equipment: backpack, towed barge, and boat mounted electrofisher (i.e. stunboat**)**. All models have two electrodes which deliver current into the water. When a fish encounters a large enough potential gradient, it becomes affected by the electricity. Usually pulsed DC current is applied, which causes galvaganaxis (i.e. uncontrolled muscular convulsion that results in the fish swimming toward the anode).

Electrofishing usually requires one person to operate the anode, and another person to catch the stunned fish with a dip net. Backpack electrofisher generators are either battery or gas powered. They employ a transformer to pulse the current before it is delivered into the water. The anode is located at the end of a long pole and is usually in the form of a ring. The cathode is a long braided steel cable that trails behind the operator. Safety features (e.g. audible speakers that sound when the unit is operating, tilt-switches that incapacitates the electrofisher if the backpack is tilted more than 45 degrees, and quick-release straps to enable the user to quickly remove the electrofisher in the event of some emergency) vary with the electrofisher model.

On July 2008, experienced personnel from FWS, DAR and DOWFA attempted to use electrofishing to capture tilapia at the Kawaiele site using a backpack electrofishing unit. The team tested the main pond at 6 ppt and 3 isolated wet spots at 12 ppt, 16 ppt, and 40 ppt but the unit did not provide an effective field and fish were not stunned. It appears that e-fishing with a backpack unit will not be a viable tool for this project. However, it is possible that after the base reconfiguration is completed, boat electrofishing turns out to be an effective tool to assist in the eradication efforts of tilapia from low salinity ponds, especially if combined with other methods, such as netting (J. Herod, FWS, Pers. Comm.).

The DAR owns a boat mounted electrofishing unit. Personnel needs would vary with the number and area of ponds that qualify for this treatment.

Method 4: Blasting/ Explosives

While most applications of explosives in fisheries have been carried out for sampling purposes (Bayley & Austen 1988; Keevin et al. 1995; Metzger & Shafland 1986), we found a report of at least two experiments that looked at the efficacy of explosives to kill invasive fish: Johnston (1961) used dynamite to kill longnose gar (*Lepisosteus osseus*) from large coastal streams in North Carolina, and the California Dept. of Fish and Game used detonation cords to kill Northern Pike in Lake Davis, California (California Department of Fish and Game 2002). Detonation cord is a flexible, rope-like material containing an explosive core, usually pentaerythritol tetranitrate (PETN). It has a wide variety of applications in the mining and construction industries.

The detonation of explosives in or near water produces post-detonation compressive shock waves characterized by a rapid rise to a high peak pressure followed by a rapid decay to below ambient hydrostatic pressure. Subsequent pressure deficit causes most impacts on fish, but other aquatic organisms are expected to suffer damage as well. The primary site of damage is the swim bladder, the gas-filled organ that permits most pelagic fish to maintain neutral buoyancy. Kidneys, liver, spleen, and sinus venous also may rupture and hemorrhage (Wright & Hopky 1998). Once detonation occurs and the air bladder within affected fish is damaged, most of the dead fish will float to the top of the water surface, though some may sink to the bottom if air is forced completely out of the body cavity (California Department of Fish and Game 2002).

The degree of damage is related to type of explosive, size and pattern of the charge(s), method of detonation, distance from the point of detonation, water depth, and species, size and life stage of fish. Explosive shock waves affect both fish eggs and larvae. Larval fish would be expected to be less sensitive than those in which the swim bladder has developed, but a number of studies have found increasing sensitivity to blasting with decreasing fish size (Govoni et al. 2008). In addition, vibrations from the detonation of explosives may cause damage to incubating eggs. Sublethal effects, such as changes in behavior of fish, have been observed on several occasions as a result of noise produced by explosives. The effects may be intensified in areas of hard substrate (Wright & Hopky 1998).

The detonation of explosives may be lethal to marine mammals and may cause auditory damage under certain conditions. The detonation of explosives in the proximity of marine mammals also has been demonstrated to induce changes in behavior. Limited data indicates that the number of shellfish and crustaceans killed by the detonation of explosives is believed to be negligible, but sublethal effects of explosives on shellfish and crustaceans including behavioral modifications are little known or understood (Wright & Hopky 1998).

Metzger & Shafland (1986) and Bayley & Austen (1988) compared the efficiency of the use of detonation cord for sampling fish to that of rotenone in canals, lake areas, and ponds. In both studies, researchers used Reinforced Primacord® (10.63 g PETN.m^{-1}) and rotenone-based piscicides (Noxfish at 2 mg of active ingredient per L (mg a.i. L^{-1}) and Prentox at 3 mg a.i. L^{-1}, respectively) followed by neutralization with potassium permanganate. Their results differed greatly: while Metzer & Shafland found that detonating cord was a preferred alternative to toxicant sampling with rotenone, Bayley &Austen concluded that efficiency of this method varied with site characteristics, and that under their experimental conditions, retrieval efficiency was always greater for rotenone samples than for Primacord samples. The later authors recognized specific advantages of detonating cord over rotenone (i.e. cost-effectiveness under certain conditions, no chemical residues, absence of chemical escapement from target area) but recommended Primacord as a tool for estimating fish abundance only in deep-water areas (> 6 feet) free of obstructions, or when excessive wind would cause rotenone to escape before it could be detoxified, leading to nontarget fish kills.

Primacord® is usually measured in grams of PETN per meter of detonating cord, or in number of grains of explosive per foot. One grain of explosive contains approximately 0.06 grams of PETN (Dyno Nobel Inc. 2009). Metzer and Shafland (1986) set parallel strands of detonation cord with a load of 50 grains PETN per ft. at mid-water or deeper at intervals of 29.4 ft. or less depending on specific site conditions (e.g., depth and vegetation) in areas blocked with netting. At two lake detonation sites, 60% (94 of 157) of tagged fish released into the blocked area were recovered. They found that five species of fish stationed within 21.6 feet of a single strand of detonation cord were killed instantly upon detonation and 88% were killed at the maximum tested distance of 27.8 feet. This study was designed to evaluate the use of detonation cord for sampling fish. It doesn't provide information on the magnitude of mortality beyond 27.8 ft from the detonation cord explosion. However, it does indicate that all five species tested were killed at 21.6 feet.

In the experiment to control pike in Lake Davis, the CDFG laid approximately 900 feet of Primacord® (50 grain per ft for estimated 10.8 g PETN m^{-1}) in a rectangle of 400 feet by 40 feet across the mouth of Mosquito Slough, an area of soft and silty substrate. The cord was anchored in steel posts and was suspended about midway in the water column, which ranged from 3 to 10 feet in depth. Four electric blasting caps were used to ignite the cord. Submerged "cars" containing pike were placed at various distances from the detonation cord at 5.75-foot intervals in order to determine the radius of effect of the explosive. All fish enclosed in the suspended cages at distances less than 28 feet were killed (Paulsen 2002), but in the end, the CDFG found detonation cord not to be a successful means for eradication during the pike project (A. Rossi, CDFG, Pers. Comm.) Instead, Phase II of that project consisted of chemical treatment of the lake with a rotenone-based piscicide, Legumine CFT, which was considered successful.

The applicability of detonating cord to kill tilapia in the Kawaiele site will be dependent on the depth of the ponds that will be created after the base reconfiguration. As it was mentioned above, the relative efficiency of Primacord decreases in shallow waters (<6 feet), thus we expect that only a few ponds would qualify for this method.

Based on the information derived from the experiments mentioned above, we estimate that treating a 2 acre-pond would require approximately 2,500 feet of 50 grain per ft. Primacord. To calculate this figure we assumed a range of kill of 30 feet from the detonating cord layout, i.e., if the cords are laid in a 400 feet by 40 feet rectangle in the deeper area of the pond, and the explosion kills fish at a maximum distance of ~ 30 feet from the cord, a 900 feet Primacord would be enough to treat a 0.7 acre-area.

The handling and detonation of explosives requires specific safety procedures in accordance with regulatory guidelines of all relevant federal, state and local agencies and must be carried out by highly trained, experienced, licensed personnel. Federal regulatory guidelines are set by the Mining Enforcement and Safety Administration (MESA), the Federal Bureau of Alcohol Tobacco, and Firearms (ATF) and the Mining Safety and Health Administration (MSHA). Local regulations that must also be observed are those set by the Hawaii Occupational Safety and Health Division (HIOSH) for hazardous materials and explosives. The detonation team leader (and other team members if necessary) must have or obtain a Certificate of Fitness for Explosives in accordance with Section 12-58-1, Hawaii Administrative Rules (HAR). Other permits required are associated with the movement and suspension of sediments which may require various Water Quality Permits from the HDOH, in accordance with both the Clean Water Act (potentially sections 401 and 402) and State Legislation (HAR, 11-54). In addition, potential impacts on endangered and threatened avian fauna may occur during the implementation of the project, especially due to noise caused by the explosions, thus consultation with FWS must happen concomitantly to planning.

The fact that the Kawaiele site is in a remote location should be in this case a positive factor, as the noise of explosions would not disturb urban areas. However, it would be important to consult with the US Military due to the Kawaiele's proximity to the Pacific Missile Range Facility. Consideration should also be made regarding possible impacts of explosion noise for marine and terrestrial mammals that may transit in the vicinities. Based on the Lake Davis experiment, public acceptance is expected to be neutral to good, depending on public involvement and education regarding the method.

Method 5: Biocontrol

Biocontrol, or biological control, refers to the introduction or enhancement of a population of organisms that are predators, competitors, parasites or pathogens of a target species, such as unwanted invasive fish.

The use of living organisms to control pests is an ancient practice which can in certain instances be beneficial but in others detrimental. In general, biocontrol practices present low risks to human health, can be inexpensive and tend to be well accepted by the general public. However, examples of biocontrol programs that have backfired causing long-term negative environmental impacts abound (Bax et al. 2001; Mack et al. 2000).

There are three general approaches to biocontrol: 1) the introduction of a non-native biocontrol agent; 2) the improvement of existing natural enemies through mass production and periodic release of natural predators, competitors, parasites or pathogens of the pest; and 3) ecosystem enhancement, which involves manipulating factors that may limit the effectiveness of natural controlling agents, such as nutrients or third species. Also the release of genetically altered sterile pests can be used to disrupt the breeding of some pest organisms, but this technique requires much more complex and expensive procedures and is limited to few species.

The difficulties associated with developing an efficient biocontrol program are many and usually derive from the still limited understanding of species adaptation, niche plasticity and functional variability in biological communities. Frequent problems of biocontrol programs are related to long-term impacts of biocontrol agents on non-target species and/ or on natural resources such as food and space. For instance, it is common that a species introduced to compete with or prey on a pest will find an alternative niche and manage to coexist with the pest. Instead, they may displace the target pest but also other beneficial species and by doing so become a pest as well.

Post-introduction changes in behavior and even in the physiology of biocontrol agents can defeat the purpose of the biocontrol effort all together. These adverse outcomes can occur not only when a non-native species is introduced as biocontrol agent, but also when a species native to the treatment region is introduced to a treatment site where it was absent or when the augmentation of a native species is attempted. Thus, careful consideration of potential adverse effects is necessary; managers should try to model post-introduction population dynamics in order to prevent unexpected outcomes.

There are various cases of biocontrol efforts gone wrong in Hawai'i. In fact, our target species is a good example of organism that, along with *Gambusia* spp., has been introduced to natural water bodies for the purpose of controlling mosquitoes, a practice that has been proved to be overall inefficient (Bax et al. 2001).

Mass stocking of a predator species may reduce populations of invasive fish but is unlikely to result in complete eradication. In Australia, where tilapia (*T. mariae* and *O. mossambicus*) is a major nuisance, researchers have experimented with biocontrol using native barramundi and mangrove jack as control agents. This practice seems to impact tilapia numbers but not to solve the problem completely. In a small reservoir, researchers have combined biocontrol with electrofishing. After 18 months of treatment, a reduction of juvenile *O. mossambicus* was observed, but the final outcome is yet to be evaluated (J. Russel, and A. Webb, DPI Australia, Pers. Comm).

It is not presently known if any fish native to Hawaii is an effective predator of tilapia. Milkfish (awa, *Chanos chanos*), jacks and barracuda, all predator species by nature, have been released in Kawaiele waters in the past but we have no information on the fate on these fish. There are concerns that these candidate biocontrol agents may not be able to survive or reproduce in the salinity ranges observed at Kawaiele. Nevertheless, these and other predators should be considered for post-treatment introduction to the Kawaiele site, to keep recurrent invasions in check. For that end, fish experts should be consulted and experiments with potential predators should be carried out.

<u>Method 6: Piscicides</u>

It is a consensus among experts that chemical methods are often the most cost-effective options available for managers, and sometimes the only actually capable of achieving the expected control goals (Finlayson et al. 2000; Ling 2003; Meronek et al. 1996) (Finlayson et al. 2000; Kamrin 1997; Lennon et al. 1971; Mack et al. 2000; Madsen 2006; Netherland et al. 2005; Poovey & Getsinger 2005). However, it is important to mind that in every instance in which toxicants or pesticides are used as a management tool, the ecology of the treated system is inevitably disrupted.

Potential negative impacts of the use of chemicals include direct and indirect harm to non-target species (humans included), the development of pest resistance to pesticides, and secondary pest outbreaks. Depending on the chemical nature and formulation of the pesticide, and on the conditions and properties of the application site and application methods, the active ingredient may be transported in the environment through particle drift, evaporation, leaching or yet by residues on treated species. In addition, certain pesticides have the potential to persist in the environment for extend periods of time and may cause the contamination of adjacent soil, groundwater, superficial water, and air leading to indirect harm to non-target species. In cases where pesticides transport and off-site contamination seem possible, managers should strive to forecast potential routes and model chemical dispersion and degradation. Various methods exist to compose such forecast models. For instance, potential contamination of groundwater and nearby surface waters can be modeled through the use of dies and markers that are released at the application location for the pesticide and their dispersion monitored through the connected compartments of the system. Another way to predict off-site pollution by a degradable product is to estimate how far it can travel away from its application location based on the product's degradation rate and flux velocity. Other modeling tools exist and must be suited to specific site and pesticide characteristics.

Other indirect negative effects of pesticides include the bioaccumulation of the active ingredient in the food chain, or the intoxication of non-target species by the solvents used in end-product. In the past, synthetic pesticides (*e.g.* toxaphene, dichlorvos, endrin, malathion) have been widely used as fish toxicants despite negative effects to the environment and long-term risks to human and wildlife health. Organic compounds with piscicidal properties may serve as alternatives to synthetic pesticides. Most natural products tend to rapidly break down in the environment and are easily metabolized by animals receiving sub-lethal doses (Ling 2003). Nevertheless, it is important to be attentive to potential side effects from piscicidal uses of natural products as well. Depending on the circumstances, natural compounds can be highly toxic to humans and other non-target organisms; some may bioaccumulate, and alter water quality parameters in ways that can be extremely deleterious, thus the need to develop environmental and human health risk assessments for any toxicant compound and their end-use products.

Next we offer a brief overview of the federal and state laws and regulations that apply to the control of AIS in Hawaii, with special focus on the legal aspects of using chemical control methods to treat aquatic environments. Note that laws and regulations are constantly being challenged, revised, interpreted and amended, thus it is essential that managers consult with federal and state authorities for eventual updates.

Pesticide Laws

Federal Level

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), as amended by the Federal Environmental Pesticide Control Act of 1972 (FEPCA), is the principal law regulating pesticides in the US. FIFRA is administered by the EPA and this Agency is responsible mainly for the control of the manufacture, registration, and labeling of pesticides in the country.

Under FIFRA, all pesticides sold, distributed or applied in the US must be registered by the EPA. This registration is based on scientific studies showing that the pesticides can be used without posing unreasonable risks to people or the environment. Because of advances in scientific knowledge, the law requires that pesticides that were first registered before November 1, 1984 be reregistered to ensure that they meet today's more stringent standards. In evaluating pesticides for reregistration, EPA obtains and reviews a complete set of studies from pesticide producers, describing the human health and environmental effects of each pesticide. During this process, the EPA must also comply with the requirements under the United States Federal Food, Drug, and Cosmetic Act of 1938 (FFDCA), and the Food Quality Protection Act of 1996 (FQPA). At the end, and based on these results, the EPA decides on whether or not to (re)register the active ingredient, classifies it as a General Use Pesticide (i.e. one that can be sold, purchased and applied by any person) or as a Restricted Use Pesticide (RUP), determines the safety requirements that must appear on the pesticide label and approves a product label that identifies the terms of safe use of the pesticide.

According to pesticide law, the product label of a registered pesticide is a legal document and the instructions presented on it must be followed closely. The use of a pesticide in a way that is inconsistent with the label is a violation of FIFRA and can result in civil or even criminal action. One important caveat related to pesticides labels is that the use of a registered product on a pest not listed on the product label is allowed under Section 2(ee) as long as application is to an approved site stated on the label.

FIFRA requires all persons who apply pesticides classified as restricted use to be certified according to the provisions of the act, or that they work under the supervision of a certified applicator. Commercial, private and public applicators must demonstrate a practical knowledge of the principles and practices of pest control and safe use of pesticides. In addition, applicators using or supervising the use of any restricted use pesticides purposefully applied to standing or running water are required to pass an exam to demonstrate competency as described in the Code of Federal Regulations (40 CFR 171.4).

State Level

States are authorized to regulate pesticides under FIFRA and under state pesticide laws, which can be more but not less restrictive than Federal Law. The State of Hawaii passed the Hawaii Pesticide Law (Chapter 149A, Hawaii Revised Statutes) in 1981 and this law is administered and enforced by the Division of Plant Industry, State Department of Agriculture (HDOA).

The HDOA is primarily concerned with the sale, distribution, use and disposal of pesticides in the state, and all pesticides sold and applied in the state must be lincensed with the HDOA. In other words, a pesticide may be registered for use in the country by the EPA, but it can only be used in Hawaii if it is also registered by the HDOA. A list of currently HDOA registered pesticides can be found at the pesticide branch website (http://hawaii.gov/hdoa/pi/pest/SLN.pdf).

Two sections from FIFRA are particularly important for AIS rapid response or control activities: Section 18, which applies to the use of a pesticide for an unregistered use and Section 24(c), which applies to new uses or new end use products.

Section 18 of FIFRA authorizes the EPA to allow states to use a pesticide for an unregistered use for a limited time if the EPA determines that emergency conditions exist. Most requests for emergency exemptions are made by state lead agricultural agencies, although the USDA and the USDI can also request exemptions. Requests are most often made for pesticides that have other similar uses registered.

The state agency evaluates the requests and submits requests to EPA for emergency exemptions they believe are warranted. The uses are requested for a limited period of time (no longer than 1 year), to address the emergency situation only. The EPA attempts to make decisions on the requests within 50 days of receipt. During this 50-day time period, EPA must perform a multi-disciplinary risk assessment of the requested use, relying largely on data that have already been reviewed for the pesticide. A dietary risk assessment, an occupational risk assessment, an ecological and environmental risk assessment, and an assessment of the emergency are conducted prior to making a decision. For the past several years, EPA has also evaluated the risk to the most sensitive sub-population (often infants and children) in its dietary risk assessments. The Agency's evaluation also includes an assessment of the progress toward registration for the use in question.

If the emergency appears valid and the risks are acceptable, EPA approves the emergency exemption request. EPA will deny an exemption request if the pesticide use may cause unreasonable adverse effects to health or the environment, or if emergency criteria are not met. As a matter of course, a state may withdraw an exemption request atany point in the process. If a need is immediate, a state agency may issue a crisis exemption which allows the unregistered use for 15 days. The state notifies EPA of this action prior to issuing the crisis, and EPA performs a cursory review of the use to ensure there are no concerns. If concerns are noted, EPA confers with the state, and under extreme cases may not allow a crisis to be declared. If the state follows up the crisis with, or has already submitted, an emergency exemption request, the use may continue under the crisis until the EPA has made a decision on the request. If the state does not also submit an emergency exemption request, EPA must still establish the appropriate tolerance(s) for the crisis use.

Under Section 24(c) of FIFRA, States have authority to add uses to pesticides based on special local needs. States may not register new active ingredients under Section 24(c) but federal agencies or an authorized state official may request that EPA allow the use of an unregistered active ingredient or an additional use for a registered pesticide to respond to emergency conditions under Section 18 of FIFRA for a specific period of time. EPA may approve or disapprove this request.

Water Pollution Control Laws

Federal Level

Congress passed the federal Water Pollution Control Act which, with subsequent amendments, is commonly referred to as the Clean Water Act (CWA), in 1972 (P.L. 92-500).

The preamble to the CWA states that the goal of the Act is to ensure that the nation's waters are "fishable and swimmable." The 1987 Federal Water Quality Act Amendments (P.L. 100-4) placed new emphasis on nonpoint source pollution management and contained specific requirements and responsibilities for state nonpoint source pollution programs, including submittal of a Nonpoint Source Assessment Report and a Management Plan to the U.S. Environmental Protection Agency (EPA) for approval.

Three Sections of the CWA deserve mention here: Section 401, which deals with certifications, permits and licenses for discharges of pollutants; Section 402, which established the NPDES permit program to regulate point source pollution and Section 404, which addresses dredging and filling of materials.

Section 401 (Certification) of the CWA (33 U.S.C. §1251 et seq) Title IV (Permits and Licenses) requires that any applicant for a federal license or permit to conduct any activity which may result in any discharge into navigable waters, shall provide the licensing or permitting agency a certification from the State in which the discharge originates or will originate that any such discharge will comply with state effluent limitations and water quality standards promulgated in accordance with other sections of the CWA. This Section would apply to the cases of the use of pesticides in aquatic environments that fall into the navigable waters definition. Importantly, if the state denies the certification, the denial acts as an absolute veto of the federal license or permit application. The state denial in not reviewable by the permitting or licensing agency nor by the federal courts. The state decision is thus reviewable through state courts (33 U.S.C. § 1341(a)(1)).

Section 402 (use of chemicals and toxic compounds) of the CWA establishes the National Pollutant Discharge Elimination System (NPDES) permit program to regulate point source pollution into waters of the US. This section states specific discharge limits, and monitoring and reporting requirements, as well as special conditions. The EPA is charged with administering the NPDES permit program, but can authorize states to assume many of the permitting, administrative, and enforcement responsibilities in its lieu. Authorized states are prohibited from adopting less stringent standards (than those in NPDES), but may adopt more stringent standards if allowed under state law. All new permit applications are then submitted to the state agency for NPDES permit issuance.

The Coastal Zone Act Reauthorization Amendments of 1990 required Hawaii, as one of the states with a federally-approved Coastal Zone Management (CZM) Program to develop and implement a coastal nonpoint pollution control program, to be approved by the NOAA and by the EPA. State programs must be developed jointly by the coastal zone management agency (Department of Business, Economic Development and Tourism) and the water quality agency (Department of Health, DOH).

Finally, Section 404 (dredging and filling due to mechanical and/or physical control) of the CWA establishes the program that regulates the discharge of dredged and fill material into waters of the US, including wetlands. Responsibility for administering and enforcing Section 404 is shared by the US Army Corps and EPA. With EPA approval and oversight, states can assume administration of the Section 4040 permit program in certain nonavigable waters within their jurisdiction

State Level

Hawaii's Department of Heath (DOH) is responsible for controlling water pollution in the state. DOH's authority over the application of chemical products to water bodies comes from Chapter 342D (Water Pollution) of the Hawaii Revised Statues (HRS). According to it, the DOH is the administrator of that Chapter, and has as duties to "prevent, control and abate water pollution in the State" (HRS, §342D-4).

The DOH director may establish by rule, water quality standards, effluent standards, treatment and pretreatement standards, and standards of performance for specific areas and types of discharges in the control of water pollution, thereby allowing for varying local conditions (HRS,§342D-5). DOH's duties under the public trust doctrine requires the DOH to not only issue permits, but also to ensure that the prescribed measures are actually being implemented after a thorough assessment of the possible adverse impacts the development would have on the State's natural resources; this duty is consistent with the constitutional mandate under article XI, §1 of the Hawaii constitution and the duties imposed upon the DOH by this chapter and chapter 342E. (111 H. 205, 140 P.3d 985).

The definition of water pollution is broad enough to include any substance that will change the physical, chemical, or biological properties of any

State waters; and the definition of State waters include all waters, fresh, brackish, or salt, around or within the State, including but not limited to coastal waters (i.e. up to 3m of the coast line), streams, rivers, drainage ditches, ponds, reservoirs, canals, ground waters, and lakes; provided that drainage ditches, ponds, and reservoirs required as a part of a water pollution control system are excluded" (HRS §342D-1).

To give effect to this mandate, the DOH has promulgated TWO Administrative Rules: HAR,

Chapter 11-54 (Water Quality Standards, last amended and compiled on Aug 31, 2004), and the HAR, Chapter 11-55 (Water Pollution Control, last amended and compiled on Oct 8, 2007).

The Water Quality Standards consists of the general policy of water quality antidegradation. It specifies designed uses, classifies State waters, and sets the water quality certification system, criteria and standards. This HAR Chapter is commonly referred to as the "Section 401", in reference to Section 401 of the CWA (33 USC§1251), which states that "any applicant for a Federal license or permit to conduct any activity including, but not limited to, the construction or operation of facilities, which may result in any discharge into the navigable waters, shall provide the licensing or permitting agency a certification from the State in which the discharge originates or will originate, or, if appropriate, from the interstate water pollution control agency having jurisdiction over the navigable waters at the point where the discharge originates or will originate, that any such discharge will comply with the applicable provisions of sections 301, 302, 303, 306, and 307 of this title". This common reference to Section 401 may seem to imply that the existence of the state water quality certification is only necessary if a Federal license is required, but that is not the case in Hawaii. The HI State Law vests the DOH with the authority to embargo and impose penalties to projects if they don't have a state permit, are not in accordance with the state law, or don't have been given a "Variance"(§342D-7).

The other legal instrument with which the DOH exercises its statutory authority of water quality issues is the Water Pollution Control Chapter 55 of Title 11 (HAR, 11-55). This Chapter is much more geared towards the administration of the National Pollutant Discharge Elimination System (NPDES) permits CWA (33 USC§1251). In Hawaii, the DOH administers the NPDES permitting, i.e. it has to make sure all the projects that will incur discharges into water bodies are in compliance with HAR11-54, HAR 11-55, and ultimately HAR 342D; as well as with all Federal regulations and standards.

Does CWA Section 402 apply to AIS rapid response or control actions?

An interpretive statement issued by EPA in January 2005 stated that the application of a pesticide to waters of the US consistent with all relevant requirements under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) does not constitute the discharge of a pollutant (and consequently does not require a Federal NPDES permit) in the following two circumstances: 1) the application of pesticides directly to waters of the United States to control pests (e.g. applications to control mosquito larvae, aquatic weeds, or other pests that are present in the waters of the United States); 2) the application of pesticides to control pests that are present over waters of the United States , including near such waters; that results in a portion of the pesticides being deposited to those waters (e.g. the aerial application of pesticides to waters of the United States or of insecticides to a forest canopy where waters of the United States may be present below the canopy, or applications of pesticides over or near water for control of adult mosquitoes or other pests.). A decision by the United States Court of Appeals for the Ninth Circuit (*Fairhurst vs. Hagener*) reaffirmed EPA's decision that a pesticide applied to a river for the purpose of "eliminating pestilent fish species is not a pollutant for the purposes of the Clean Water Act…and thus not subject to the Act's permit requirements."

EPA notes that the application of a pesticide in violation of FIFRA is not covered by the interpretive statement, and the applicator is subject to enforcement actions under any and all appropriate authorities including, but not limited to, FIFRA and CWA. EPA has proposed incorporating the 2005 interpretive statement into regulations. Further information can be found at 70 Fed. Reg. 5093 (February 1, 2005).

On October 22, 2007, this EPA interpretation has been incorporated into Hawaii state law. The amended "Water Pollution Control Chapter" of Title 11(HAR § 11-55-04 (h)) reads exactly as the stated in the EPA's interpretative statement. That means that the state recognizes that the NPDES permit that would previously be issued through the DOH is no longer required to control invasives, as long as 1) the pesticide is registered under FIFRA (both at federal and state levels), 2) the applicator is certified by the DOA. if the pesticide is a Restricted Use Pesticide, and 3) applications are done in conformity with the product's label. However, the DOH still has grounds to claim some authority over the issue through the "Water Quality Standards Chapter" (HAR, 11-54), and its water quality certification section (HAR §11-54-9.1). Although the Federal requirement for the NPDES is clearly waived, States have the authority to exercise their own independent permitting, certification and restrictions systems according to their own water quality standards. Although the "Water Quality Standards Chapter" does not specifically address pesticides, it addresses biocides under its "Basic Water quality criteria applicable to all waters" "(a) All waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants, including (…)(4) High or low temperatures, biocides, pathogenic organisms; toxic, radioactive, corrosive, or other deleterious substance at levels or in combinations sufficient to be toxic or harmful to human, animal, plant, or aquatic life, or in amounts sufficient to interfere with any beneficial use of the water (…)"§11-54-4 (a)(4).

However, a recent court decision rested on deciding that pesticides, even those that are compliance with FIFRA, can be "pollutants" within the meaning of the Clean Water Act (See 33 U.S.C. 1362(6)). On January 7, 2009, the U.S. Court of Appeals for the Sixth Circuit decided that the EPA's rule exempting the application of pesticides from the NPDES permit requirement contravene the "clear and unambiguous" language of the Clean Water Act (*National Cotton Council of America et al. v. United States environmental Protection Agency)*.

The Court examined the meaning of "chemical wastes" and "biological material" which are defined by the Clean Water Act as being "pollutants." EPA argued that pesticides are not "waste" when they are applied in, on or near water they do not require a NPDES permit. EPA then argued that it should not treat biological pesticides any differently, so they, too, should be considered not to be pollutants. The Court held that while chemical pesticides that are applied and leave no residue or waste probably do not require a NPDES permit, any application of a chemical pesticide that produces a residue or a waste, requires a permit and that this was clearly what Congress intended when it passed the Clean Water Act. The court's decision also left no doubt that any biological pesticide required a permit, since Congress did not qualify "biological materials" with the word "waste." EPA attempted to argue that because chemical pesticides when they are applied are not "waste," the "chemical waste" produced by their application is not from a "point source," which is an exception to the permit requirement. However, the court decided that the time element relied upon by the EPA simply does not exist, and if waste is created from the application of a pesticide, then a permit must be obtained.

As the court pointed out in its decision and in a footnote, the EPA could issue a general permit for the application of pesticides and it would have almost the same effect as its rule exempting the application of pesticides from obtaining a NPDES permit. In fact, two states have already issued "general permits" for the application of pesticides: users of aquatic pesticides in Washington could discharge those pesticides covered by the rule without obtaining a permit. These general permits "greatly reduce [the] administrative burden by authorizing discharges from a category of point sources within a specified geographic area." "Once [the] EPA or a state agency issues such a [general] permit, covered entities, in some cases, need take no further action to achieve compliance with the NPDES besides adhering to the permit conditions." California is the other state that has issued a general permit.

The EPA has not yet released any formal statements addressing the court ruling or the issue. The State of Hawaii's DOH must be consulted to whether or not they intend to issue a general permit to deal with the use of biopesticides for the control of invasive species.

Other Laws and Regulations

The Endangered Species Act required federal agencies to ensure that their actions are not likely to jeopardize listed species or adversely modify designated critical habitat. A primary use of aquatic pesticides is to eliminate invasive or non-native species in designated critical habitat so threatened or indigenous species may later be restored.

The Agency has developed the Endangered Species Protection Program to identify pesticides whose use may cause adverse impacts on federally listed endangered and threatened species, and to implement mitigation measures that address these impacts. To assess the potential of registered pesticide uses that may affect any particular species, EPA puts basic toxicity and exposure data developed for the REDs into context for individual listed species and considers ecological parameters, pesticide use information, the geographic relationship between specific pesticide uses and species locations and biological requirements and behavioral aspects of the particular species. When conducted, these analyses take into consideration any regulatory changes recommended in the RED being implemented at that time. A determination that there is a likelihood of potential effects to a listed species may result in limitations on the use of the pesticide, other measures to mitigate any potential effects, and/or consultations with the Fish and Wildlife Service or National Marine Fisheries Service, as necessary. If the Agency determines use of an aquatic pesticide "may affect" listed species or their designated critical habitat, EPA will employ the provisions in the Services regulations (50 CFR Part 402).

Finally, compliance with the National Environmental Policy Act (NEPA) is required if Federal funds are used for the control program. This legislation dictates that control methods used at a public facilities must not negativelly affect native biota or existing water quality, and a protocol for compliance with the NEPA should be

Of all the substances known to have piscicidal properties, only four chemical products are currently registered by the USEPA for piscicidal uses in waters of the United States: TFM (3-trifluoromethyl-4-nitrophenol) and niclosamide, which are registered lampricides, and antimycin A and rotenone, which are general piscicides and the only toxicants registered for fish control in this the US.

Rotenone

Rotenone is a substance that has piscicidal, insecticidal and some acaricidal properties. It is extracted from the various tropical and subtropical plant species, the most common sources being the roots of the plant genus *Derris* spp., *Lonchocarpus* spp., and *Tephrosia* spp. (USEPA 2007b).

Rotenone has been used for centuries by indigenous people of various parts of the world as narcotics to capture fish for eating purposes. In the US, rotenone has been used to manage fish populations since the 1930's (Finlayson et al. 2000) and currently, there are at least ten different brands of rotenone end-use products being commercialized in this country. Rotenone is most often used to control undesired fish in standing water, such as large lakes and reservoirs, and also in rivers and streams. It used to also be applied in marine environments as a fish sampling tool (Robertson & Smith-Vaniz 2008), but the application of rotenone in marine or estuarine environments is now prohibited.

Mode of action and selectivity

Rotenone interrupts cellular respiration at mitochondria in gill-breathing animals (Fajt & Grizzle 1998; Ling 2003). In high concentration (~100-200 ppb), rotenone acts as a broad-spectrum pesticide affecting all aquatic fauna, including amphibians and invertebrates (Skaar 2001, Lennon 1971, Schnick 1974b). In lower concentration, rotenone effects seem to be somewhat selective, killing some fish such as rainbow trout (*Oncorhynchus mykiss*), bluegill sunfish (*Lepomis macrochirus*) but not others like zebrafish (*Danio rerio*) and black bullhead (*Ameiurus melas*) (Finlayson et al. 2000; USEPA 2006b).

Environmental Fate and Persistence

Rotenone is not expected to leach, contaminate ground water, nor bioaccumulate in the food web and usually breaks down completely within hours to several weeks (Cheng et al. 1972; Dawson et al. 1991; Draper 2002; Gilderhus et al. 1986; USEPA 2006b).

Unpublished data analyzed by the EPA indicates that rotenone bonds to sediment with sufficient strength that it is unlikely to leach in most circumstances, the exception being very sandy soils with low organic carbon content (USEPA 2006b).

Rotenone is highly degradable particularly in warm (≥ 25°C), clear, alkaline waters (pH> 9) and under full exposure to light. Hydrolysis and photolysis seem to be the primary routes of rotenone breakdown, but biodegradation cannot be ruled out. The breakdown of rotenone during the summertime may occur so rapidly due to concomitant high light exposure and high water temperature that this may cause difficulties during the application. Unless all parts of the water body are treated simultaneously, fish may avoid death by migrating back into treated waters in which the concentration of the active ingredient are already too low to be efficient (Ling 2003). Higher pH seems to reduce rotenone's half-life in warm waters even more. Nevertheless, aquatic field studies have shown that rotenone can persist in cold water at sufficiently high concentration to cause fish mortality for at least 25 days, even in alkaline conditions (USEPA 2006b).

The primary first-order degradation product of rotenone is rotenolone (Cheng et al. 1972; Newsome & Shields 1980; USEPA 2006b), a substance reported as less toxic than rotenone (Soloway 1976) but somewhat more persistent in the environment (USEPA 2006b). Faster neutralization by oxidation occurs when rotenone is mixed with potassium permanganate (Engstrom-Heg & Colesante 1979; Finlayson et al. 2000) and this practice is prescribed by rotenone's label, as amended in 2007 by Rotenone's Reregistration Eligibility Decision (USEPA 2007b).

Risks to Human Health and to the Environment

Rotenone is classified as Restricted Use Pesticide due to acute inhalation and acute oral toxicity and due to toxicity to fish and other aquatic organisms (USEPA 2007b). Rotenone end-use products are of moderate toxicity to mammals and avian species (Finlayson et al. 2000; Kegley et al. 2007; Ling 2003; USEPA 2007b). Human poisoning is more likely to occur as a result of inhalation rather than ingestion. Symptoms of non-lethal intoxication such as headaches, sore throats, sores on mucous membranes, skin rashes and severe irritation of the eyes have been reported in humans following prolonged occupational exposure to rotenone dusts, thus applicators should be trained and wear proper protective gear (USEPA 2006b).

As part of rotenone's reregistration process in 2007, the EPA reviewed the toxicity and environmental fate of rotenone and scrutinized the risks associated with different uses and application methods. There is no evidence that rotenone causes birth defects, reproductive dysfunction, gene mutations or cancer in animals. In a recent study, the chronic systemic exposure of lab rats to rotenone via brain injection was linked to Parkinson's disease-like symptoms (Betarbet et al. 2000). In response, registrants filed to cancel reregistration of all rotenone uses other than piscicidal ones, based on the logic that chronic systemic exposure to rotenone would be of particular concern for dust products when used in agricultural and residential settings, but not for controlled piscicidal uses.

In addition, the EPA mandated some label changes that aim to reduce risks to human health and to the environment. The new rotenone label mandates the deactivation of rotenone with potassium permanganate, encourages the collection and burial of fish killed by the treatment, prohibits the use of rotenone-products in estuarine and marine environments, establishes the maximum application rate of 200 ppb, and requires drinking water intake verification to ensure residual rotenone concentration is below 40 ppb (USEPA 2007b).

Formulations and application methods

There are currently two approved formulations for rotenone products: liquid and wettable powder. Based on the EPA's risk estimates, liquid formulations result in lower occupational exposure and are more compatible with existing closed system technologies when compared to wettable powder products. Also, liquid formulations are more stable, keeping their piscicidal properties for longer while on storage, and are more effectively dispersed in water. On the other hand, liquid preparations are petroleum-based thus more expensive, and flammable. Also, they produce noticeable tastes and odors in treated waters, thus are easily detected and avoided by fish, while wettable powder formulations apparently contain fewer potentially toxic impurities and inert ingredients that may pose risk to human health and to the environment (Turner et al. 2007b).

The traditional disadvantages associated with the liquid formulation seem to have been minimized in a newly registered end-product called CFT Legumine™, a liquid 5% rotenone formulation. According to the supplier (Prentiss, Inc.), "although new to the United States, CFT Legumine™ has been used in Europe for fish management for over a decade. The country of Norway uses CFT Legumine™ to treat large rivers for eradicating the ecoparasite *Gyrodactylus salaries* on Atlantic salmon (*Salmo salar*) smolts. In comparison to conventional rotenone formulations on the market today, CFT Legumine has several advantages, including a special emulsifier and solvent package that reduces the presence of petroleum hydrocarbon solvents. The petroleum hydrocarbon solvents that are present in conventional rotenone formulations have strong chemical odors, and often there are applicator, public health and water quality concerns that affect the public's acceptance of rotenone. CFT Legumine was designed with the goal of reducing or eliminating petroleum hydrocarbon solvents such as toluene, xylene, benzene and naphthalene. By reducing these petroleum solvents, we have been able to reduce many of the negative properties inherent with the conventional liquid formulations on the market today. CFT Legumine is virtually odor-free, and retains its efficacy without the use of any synergist. In laboratory trials conducted by the California Department of Fish and Game in 2002, CFT Legumine had essentially identical efficacy to the conventional liquid 5% rotenone formulation on rainbow trout fry at concentrations ranging from 0.25 to 2.0 ppm (i.e. 250 to 200 ppb) formulation. The California Department of Fish and Game in 2003 has used CFT Legumine™ to treat ponds to eradicate common carp (*Cyprinus carpio)*, brown bullhead (*Amerianus nebulosus*), largemouth bass (*Micropterus salmoides*), channel catfish (*Amerianus punctatus*), goldfish (*Carassius auratus*), bluegill (*Lepomis macrochirus*), and grass carp (*Ctenopharyngodon idellus*). The California Department of Fish and Game also plans to use CFT Legumine™ in stream treatments for the restoration of native cutthroat trout".

Liquid formulations may be applied using a boom or other mechanized equipment that releases the product below the water's surface, or with aircraft, backpack sprayer or other hand-held nozzle to release the product above the water's surface. Wettable powder formulations may be applied with the same above-described methods, except for the backpack sprayer, which is prohibited to reduce applicator's exposure (USEPA 2007b).

<u>Feasibility and Costs of Using to Control Invasive Fish from the Kawaiele Site</u>

Rotenone is a well known piscicide in terms of the large number of control and eradication projects that have utilized the product, as well as in terms of the number and breath of toxicological studies and tests that have scrutinized its chemistry, safety and efficiency.

The Kawaiele site characteristics seem to be fairly appropriate for successful application of rotenone. The water's high pH and high temperature should promote fast natural degradation of the active ingredient, thus contamination of surface areas beyond the treatment site is expected to be minimal, if any. There are no aquatic organisms in the site that need to be spared, thus rotenone's low selectivity should not be an issue. Negative impacts on waterfowl is also expected to be negligible since a) fish carcasses will be collected and properly disposed after treatment and b) a bird would have to consume unrealistic amounts of contaminated fish carcasses to suffer an intoxication. Risks to human health are considered to be low, and should be counteracted with the use of proper application gear.

Some uncertainty remains regarding the potential contamination of groundwater by rotenone. As mentioned above, rotenone is not expected to bind with organic matter or to leach into most soils, except for sandy bottoms. The bottom sediment of the Kawaiele site is sandy but covered with a dark layer of organic matter. Uncertainty thus exists regarding the potential for the chemical to permeate through the bottom and into groundwater. Further analysis of the site hydrology and perhaps experiments with dies (as explained before) would clarify this concern.

In general, public perception towards the application of any pesticide to the environment, especially to water bodies, is negative. People usually fear for human intoxication and negative impacts on local fauna and flora, which are common side-effects of chemical products that have been used as pesticides. Fortunately, rotenone is a biopesticide of low toxicity to non-gill breathing animals, low environmental persistence and that does not bioaccumulate in the food web, so most of these concerns are actually mismatched. Nevertheless, public opposition to projects that intend to use rotenone to control invasive species is a recurrent problem (Bailey 2007) and requires special attention during the pre-treatment phase in order to avoid repercussion that may escalade into legal action. It is very important that the public is properly educated about the importance of the invasive species control plan and about rotenone, its biological origin, metabolisms and risks before the project is implemented. Workshops and meetings with stakeholders and local community representatives should be organized and the project properly discussed and approved.

Currently, there is only one end-use product licensed for piscicide applications in Hawaii, Prentiss Prenfish Toxicant (liquid, 5%) (EPA Registration #655-422). This product's state registration is due to expire on December 31st of 2009. Two other formulations in market were identified as alternatives to kill tilapia in the Kawaiele site: Prentiss Rotenone Fish Toxicant Powder (powdered, 7%), and CFT Legumine™ (liquid. 5%).

Rotenone Fish Toxicant Powder is considered to be less suitable to this project than liquid formulations, because it involves more complex preparation and application procedures (see previous section). The costs associated with the shipment of this material to Kauai, transportation to the site and emulsification before application also seem to be considerably higher than the other alternatives.

We estimate that treating the entire site with Prenfish Liquid Toxicant (5%) would cost between US$ 3,600 and US$ 5,400 plus freight costs (~US$ 500), neutralization costs (see Neutralization Section bellow) and application costs. This estimate is based on the following information: Prenfish Liquid Toxicant costs ~US$ 60 per gallon but it is sold in units of 30 gallons. 1 gallon treats 1 acre foot at ~200 ppb of a.i. (concentration for total kill), thus to treat the total volume of 60-70 acre foot in Kawaiele site, it would be necessary the purchase of 2-3 units of 30 gallons each (R. Fisher, Prentiss, Inc., Pers. Comm., see email in appendix 2).

The same treatment using Rotenone Fish Toxicant Powder (7%) would cost between US$ 1,600 and US$ 1,900, considering that 1 lb treats 0.123 acre foot of volume at ~200 ppb, and that 1 lb of the product costs US$ 3.25. Shipment costs, however, are expected to be substantially higher.

Finally, performing the treatment with CFT Legumine, would cost between approximately US$4,500 and US$ 5,320, plus application and freight costs (similar to that of Prenfish Liquid Toxicant). A gallon of CFT Legumine costs US$ 76 and treats an acre foot at 200 ppb for total kill (R. Fisher, Prentiss, Inc., Pers. Comm.). While slightly more expensive than the other two rotenone products considered above, CFT Legumine is the most promising rotenone product in terms of reducing negative impacts related to solvents and still benefiting from practical and safer application procedures. Reports of successful eradication and control projects that used this product corroborate our preference for the use of CFT Legumine (http://www.dfg.ca.gov/lakedavis/enviro-docs/).

Additional costs that need to be considered are related to registering CFT Legumine, Rotenone Fish Toxicant Powder with the state of Hawaii, or reregistering Prenfish Liquid Toxicant, if the application is to be carried out after Dec. 31, 2009.

Antimycin A

Antimycin A (chemical formula $C_{28}H_{40}N_2O_9$) is a naturally occurring substance extracted from cultures of actinobacteria of the genus *Streptomyces*. It exhibits antifungal, insecticidal and miticidal properties, and exceptional piscicidal properties (Hamilton et al. 1969).

Antimycin A was first isolated in 1945, registered as a fish toxicant in 1960 and has been used sporadically over the past decade to restore US Federally-listed threatened and endangered fish to their native habitats, being applied to both closed systems (*e.g.* ponds and lakes) and flowing waters (*e.g.* rivers and creeks). Antimycin A's most frequent use is in recreational fishing and aquaculture industries to remove scaled fish from catfish fingerling ponds.

Mode of Action and Selectivity

Antimycin A causes death by oxygen deprivation at the mitochondria, in a process similar to the one provoked by rotenone. However, the effects of antimycin A in fish are irreversible and once fish are exposed to effective doses, they will not recover if placed in clean water (Chapman et al. 2003). At lower rates (5-10 ppb), antimycin A acts as a selective piscicide, eliminating some fish including salmonids, but not others such as catfish (order Siluriformes), shortnose gar (*Lepisosteus platostomus*), bowfin (*Amia calva*) and goldfish (*Carassius auratus auratus*). At higher rates (15-25 ppb), it causes complete fish kills (USEPA 2007a). The piscicide has generally been found to be less toxic to bottom-dwelling invertebrates than to fishes (Finlayson et al. 2002).

Environmental Fate and Persistence

Due to Antimycin A's recent advent and limited usage environmental persistance and toxicological data are scarce. Models indicate that antimycin A is not likely to persist in the environment, nor to bioaccumulate; its low vapor pressure and Henry's Law constant limit its volatility (USEPA 2007a). Some studies suggest that hydrolysis is the primary route of antimycin A degradation (Lee et al. 1971; Walker et al. 1964), but aerobic processes may also interfere in antimycin A's metabolism (USEPA 2006a). Degradation products are believed to include blastmycic acid, antimycin lactone, and antimycic acid (Walker et al. 1964), but there is no quantitative information regarding the relative concentrations.

Antimycin A degrades rapidly upon contact with water under static conditions, but degradation time varies greatly from hours to over a month (USEPA 2006a). Although sorption studies for antimycin A are not available, once the compound is bound to sediment it is not expected to be bioavailable and any amount of antimycin that may desorb is expected to degrade rapidly. Antimycin A' degradation rate has been described as inversely related to pH, but observed values have differed greatly among studies (Lee et al. 1971) and recent observations indicate the relationship may not actually exist (USEPA 2006a).

Risks to Human Health and Environment

Antimycin A is classified by the EPA as a Restricted Use Pesticide (RUP) due to its aquatic toxicity and the need for highly specialized applicator training to minimize human exposure (USEPA 2007a).

The EPA has recently approved antimycin A's reregistration process, despite major discrepancies on toxicological and metabolism studies. The agency concluded that human health and ecological risks could be reduced beyond their level of concern upon reduction of human and other non-target organisms' exposure to the product (USEPA 2007a).

The EPA concluded that Antimycin A is not a dermal irritant, and eye irritation resolved within 48 hours following exposure (USEPA 2006c) but label amendments for antimycin A prohibit the use of treated water for swimming, drinking or irrigation until measured antimycin A residues drop below 0.015 $\mu g. L^{-1}$. The potential effects of consuming fish killed by antimycin A are not completely understood, thus the amended label for Antimycin A end-product states that fish killed by antimycin A must not be consumed; they should be collected and buried. Harvesting of surviving fish after a selective kill in aquaculture ponds must be precluded for 12 months.

There are no data available for chronic toxicity. A 90-day subchronic rat study resulted in a lowest-observed-adverse-effect level of 0.5 mg/Kg/day. A no-observable-adverse-effect level was not established and no other relevant adverse effects were observed. There are no data for reproductive, developmental, mutagenicity, nor carcinogenicity effects of antimycin A.

At concentrations used to control pest fish populations, antimycin has been considered to have minimal effects on other aquatic organisms (Finlayson et al. 2002). Fish and other aquatic organisms have been found to be more sensitive to antimycin than are mammals and birds. Direct effects of antimycin A applications on terrestrial plants and animals are expected to be minimal (Finlayson et al. 2002).

Antimycin A was reregistered by the USEPA in 2007 provided that the label is amended to include, among other provisions, the prohibition of its use in marine or estuarine environments, the mandatory deactivation of treatment outflow with potassium permanganate, the prohibition of harvesting of surviving fish from selective kill use for 12 subsequent months, establishment of maximum application rate of 25 ppb, prohibition of public access to the treated site for 7 after treatment completion (USEPA 2007a).

Formulations and Application Methods

The only formulation of antimycin currently registered with the EPA is a concentrate of 23% active ingredient (Fintrol-® Concentrate, EPA Registration Number 39096-2, Aquabiotics Corp.). Fintrol® concentrate comes in a kit containing crystalline antimycin along with a diluent consisting mostly of acetone with other inert ingredients. Metering pumps, sprayers, and gravity-fed drip systems have all been successfully used to apply the concentrate to streams and shallow waters (Gilderhus et al. 1969, Lennon and Berger 1970, Engstrom-Heg 1971, Stefferud and Propst 1996). Fintrol® concentrate can be applied to lakes and ponds with metering pumps or sprayers attached to motorized boats. The concentrate is applied to the propeller wash to aid in mixing. Deeper water can be treated using metering pumps connected to weighted perforated tubing that is lowered to the desired depth.

Feasibility and Costs to eliminate Invasive Fish from the Kawaiele Site

Fintrol, the only antimycin A-based piscicide, has never been licensed for use in the State of Hawaii (HI Dept.Ag. 2008) and for this reason the permitting process for this method is expected to be more problematical than that for rotenone. Also, Antimycin is a relatively new active ingredient and the level of uncertainty regarding its degradation and long-term risks to human health and ecosystems is still considerable. Especially, when compared to rotenone, the number of conclusive studies and experiments performed with antimycin is precarious.

If it were to be used to eliminate invasive fish from the Kawaiele site, we estimate that it would cost between U$ 13,000 and 15,000 to treat the entire site, plus application and freighting costs. This figure was estimated based on the following information: 1 unit of Fintrol (16 oz.) costs $400 and treats 7.5 acre-feet at 5 ppb (M. Romeo, Aquabiotics, Inc., Pers. Comm.). Thus, in order to treat the entire site (60-70 acre foot) at 20 ppb of antimycin A (for complete kill in high pH) it will be required an application of between 32 and 37 units of Fintrol concentrate. Note that these estimates are based on present figures and may need to be updated for future cost analyses. Also, it is important to consider that at the moment there is only one supplier of antimycin A-based piscicides in the US (i.e. Aquabiotics, Inc.) and a project utilizing this method will be hinged on the availability of the product from this one supplier. In fact, the supplier is currently out of Fintrol, and their representative does not know when they will have it available again (see appendix 2).

Neutralization with Potassium Permanganate

Potassium permanganate is one of the most widely used inorganic chemicals for the treatment of municipal drinking and wastewater; it is commonly used to oxidize iron, manganese, and arsenic, to remove color and to treat for biofilm in raw water intake pipes. Potassium permanganate is also used in fish farming to prevent or alleviate oxygen shortages in rearing ponds. It works by oxidizing decaying plant matter and other organics so that they consume less oxygen, thereby relieving oxygen depletions that otherwise could result in fish kills.

In the fisheries management realm, potassium permanganate has been used to neutralize the effect of piscicides that contain rotenone and antimycin A, especially in lotic systems to prevent exposure beyond the defined treatment area. Neutralization with potassium permanganate ($KMnO_4$) of water bodies that have been treated with rotenone or antimycin A became a mandatory practice after the issuance these active ingredients' reregistration decisions (USEPA 2007a, 2007b).

Monitoring data indicate that deactivation of rotenone by potassium permanganate can be relatively effective. Water temperatures less than 50° F can result in longer times (and distances) required for detoxification. Potassium permanganate reduces the half-life of antimycin to 7 to 11 minutes in a laboratory setting and is a strong oxidizing agent that quickly breaks down to naturally occurring compounds. Organic material and inorganic oxidation substances rapidly decrease the activity of potassium permanganate (Archer 2001).

Potassium permanganate can be highly toxic to freshwater fish and its toxicity is inversely related to temperature. The amount and duration of use depends on a number of environmental factors and the quantity of toxicant to be deactivated. In the laboratory, exposure to 2 $mg.L^{-1}$ of KMnO4 was lethal to rainbow trout (*Oncorhynchus mykiss*) within hours (Archer 2001). When applied at 1.5 $mg.L^{-1}$ in the absence of readily oxidizable substances, potassium permanganate achieved lethality in westslope cutthroat trout (*Oncorhynchus clarki lewisi*) after 16 to 24 hours of exposure (Turner et al. 2007a).

Potassium permanganate is quickly broken down when it reacts to organic material to antimycin or to rotenone in water. Breakdown components of potassium permanganate (i.e. potassium, manganese, and water) are common in nature and have no known deleterious environmental effects at concentrations used for neutralization of piscicides (Finlayson et al. 2000).

Since high dosages of permanganate may be toxic to aquatic organisms, detoxification procedures should utilize calibrated equipment to achieve minimum effective concentration of permanganate to neutralize the piscicide. The concentration of both the pesticide and the neutralization compound can be monitored with the utilization of analytical chemistry techniques, such as HPLC (high performance liquid chromatography). Alternatively, monitoring stations consisting of caged live fish can be placed at the downstream limit of the treatment area to verify detoxification of the piscicide and potassium permanganate.

Finlayson et al. 2000 reports the existence of dust, crystal and aqueous formulations of KMnO4 and recommends the aqueous solution (5%) for being easier to dissolve and apply. These authors highlight that incidents of accidental release of rotenone into nontarget areas have been attributed to the erroneous rule of thumb that rotenone is neutralized with $KMnO_4$ at a 1:1 ratio. This rule is approximately true for distilled water, but several components of most natural waters alter the relationship. Controlled experiments demonstrated that dissolved electrolytes and suspended organic matter have a major influence on the amount of $KMnO_4$ required to neutralize a given concentration of rotenone. A formula to account for organic demand and total hardness generally encountered in natural systems was developed by Engstrom-Heg (1972). This author showed that the amount of $KMnO_4$ required to neutralize a given concentration of rotenone needs to be multiplied by the product of the following formula to account for organic and electrolyte demands:

Multiplier = 1 + 0.002 (total alkalinity [as ppm $CaCO_3$] – 20) + 0.5 (organic demand [as ppm])

The information necessary to calculate this multiplier for the tilapia control in the Kawaiele site and consequent cost of neutralization with potassium permanganate is not available at this time. Finlayson et al (2000) reports that in 1999, the cost to treat one acre-foot of water at 1 ppm used to range from US$0.20 to US$0.34 for granular KMnO4 and US$ 1.-4 for the 5% aqueous solution; the dry forms of potassium permanganate used to cost between $1.50 and $2.50 per lb. A recent estimate was requested from various potential suppliers, including Western Chemicals (Ferndale, WA, Ph:1-800-283-5292), Schall Chemical, Inc. (Monte Vista, CO, Ph: 719-852-3921) and Industrial Supply Co. (Arvada, CO, Ph: 303-744-

6149). Potassium permanganate is currently sold in units of approximately 50 lbs each, at about $3.30 per lb. plus shipping costs. If we suppose that the optimal concentration of potassium permanganate to neutralize rotenone in the Kawaiele is no more than 1 ppm, then we would need less than 10 lbs of $KMnO_4$ to neutralize the whole site (i.e. ~60-70 acre feet in water volume).

Fish collection and Disposal

Regardless of the methods chosen to conduct the control and eradication of tilapia in the Kawaiele site, subsequent collection and disposal of dead fish will be required to prevent the contamination of birds with bacteria associated to the process of decomposition of fish carcasses. Special concern exists regarding the risk of endangered waterfowl by botulism (A. Henry, FWS, Pers. Comm.).

Fish collection during and after standing water treatments is usually accomplished with multiple boats and dip nets. Following treatment, crews are organized to patrol the ponds and collect dead fish, which is expected to float to water surface. Dead fish must then be transported to a disposal site: a landfill or burial site for example. Arrangements must be made in advance of the treatment to locate a suitable permitted disposal location (Finlayson et al. 2000). One alternative to dispose of dead tilapia collected post-treatment from the Kawaiele is to bury the carcasses in some nearby dry location, but this topic must be further considered and planned. The viability of using other types of nets (e.g. purse nets) to expedite the collection of carcasses should also be considered.

Comparative Analysis

Method	Pros	Cons
Dewatering	• Very effective (if complete) • Low risks to human health and applicators' safety • Not persistent • Neutral-positive public perception • Easy permitting process	• Very expensive • High risk of spreading invasive fish into adjacent systems • High risk of polluting adjacent systems with sediments and microorganisms
Netting and trapping	• Cost competitive (if most personnel needs are satisfied by volunteers) • Not persistent • Often positive public perception • Easy permitting process	• Not very effective • Success depends greatly on expertise of personnel • Requires a large number of personnel, thus complex logistics
Electrofishing	• Not persistent • Often neutral public perception • Easy permitting process	• Not effective in high salinity (i.e. it is an option only if salinity drops in certain ponds after base reconfiguration) • Requires specific technical expertise
Blasting/ Explosives	• Not persistent • Public perception is expected to be neutral	• Effectiveness is disputable; expected to be efficient only in deep areas (i.e. it is an option only in certain areas >5 feet deep) • Requires specific technical expertise and licensed personnel • Complex permitting process
Chemical treatment (Rotenone/ Antimycin A)	• Very effective • Low risk to human health if applied correctly • Not persistent	• Risk of groundwater/ adjacent systems contamination has not been measured • Complex permitting process • Often negative public perception (requires public education /outreach campaign)
Biocontrol	• Neutral-positive public perception • Long-term benefits (if appropriate species are used)	• Variable effectiveness • Risk of unwanted outcomes is high

Conclusions and recommendations

The objective of this preliminary plan was to identify and evaluate methods that could be applied for the control and eradication of tilapia in the Kawaiele site. It is our understanding that an optimal plan will integrate more than one of the methods described before (see Comparative Analysis section above). Considering the limitations imposed by the site, the target species characteristics and the lessons learned from similar control projects carried out elsewhere, we identify a combination of chemical treatment with rotenone, preferably CFT Legumine, with secondary methods (e.g. netting and possibly biocontrol) as the most promising alternative.

Dewatering the site completely is impractical and cost-prohibitive; while water levels are expected to naturally decrease in certain ponds after the base reconfiguration is completed, especially during the summer, it does not seem like water level reduction is an option that could reduce the population of tilapia. Likewise, electrofishing may serve as an adjunct method to netting in certain ponds of lower salinity after the berms are raised, but it does not stand out as a successful method. Blasting the tilapia with detonating cords may work in some deeper ponds, but reports of previous attempts to control invasive fish using this method indicate that accomplishing eradication goals with detonation is unlikely and require complex logistics, testing and permitting that may just not pay off.

Netting appears to be a great candidate for its relative low risks to personnel and general public approval, but it is certainly not expected to result in major reduction of tilapia population, especially because of these fishes' capacity to avoid capture. Also, costs of a netting operation in the Kawaiele site are expected to be considerably high due to its remote location and the need to transport the large number of personnel and volunteers that would be required to perform such operation. Nevertheless, we believe netting should be further considered as an auxiliary method for a chemical treatment. Likewise, biocontrol strategies utilizing native species should be further considered for post-chemical treatment maintenance.

Important lessons can be drawn from efforts to control invasive fish in other localities. For instance, in Lake Davis, CA, the CDFG tried several methods to kill invasive Northern Pike with different levels of success (go to http://www.dfg.ca.gov/lakedavis/enviro-docs/ to see documents pertaining to this project). The project started in 1997. Experts feared that if pike escaped Lake Davis, it could rapidly extinguish the state's fragile salmon and steelhead trout runs. Methods to eradicate pike from Lake Davis included unsuccessful applications of rotenone, electrofishing, netting and explosives. Successful impact on the population size of Northern Pike, however, was only accomplished in 2007 when a major chemical treatment was executed by applying more than 15,000 gallons of the rotenone-based CFT Legumine (Bailey 2007).

Rotenone and antimycin A are the only two pesticides currently registered for fish control activities. While these two toxicants A are in many ways similar (e.g. mode of action, low selectivity) they do have certain characteristics that make them more suitable to some environments and target species than to others. In large bodies of standing water, antimycin A is not as effective as rotenone primarily because of antimycin A's short persistence and the difficulty of dispersing the product throughout the water column. It tends to give better results in running water, streams, and shallow waters while rotenone can be efficient in either lotic or lentic environments (Turner et al. 2007a). On the other hand, antimycin is often regarded as being less harmful to non-target aquatic organisms (especially invertebrates) than rotenone.

Lennon et al. (1971) stated that antimycin is the ideal piscicide because it is more selective than rotenone; it is effective at low concentrations in a wide range of water quality; it is not repulsive to fish; and it leaves no toxic residue. While most of these authors' assumptions seem to be in agreement with some research, many questions remain regarding antimycin A's toxicity, metabolism and fate in the environment (USEPA 2006a). Notably, there are numerous gaps in what concerns the understanding of potential long-term impacts of the application of either rotenone or antimycin A. When contrasting the number of studies that have been published regarding their toxicology and fate in the environment, however, it is obvious that rotenone has been much more studied that antimycin A. That is only logical, considering that rotenone has been used as fish toxicant (and as insecticide) for centuries in various parts of the world, while the isolation of antimycin A is a fairly recent development. While the gaps in knowledge remain, the level of uncertainty regarding the known facts seem to be lower in the case of rotenone. Moreover, the number of registered end-use products and companies that manufacture rotenone-based products is substantially greater than the corresponding for antimycin A. In fact, there is currently only one company (Aquabiotics Ltd.) that produces a single antimycin A-based toxicant (Fintrol). Ultimately, this discrepancy in the variety of products and registrants represents a limitation on the options managers have when choosing among formulations, application methods and non-active ingredients (e.g. surfactants and solvents) that best suit their eradication and control projects.

Tilapia species are highly invasive and exist under feral conditions in every nation in which they have been cultured or introduced (Canonico et al. 2005). These and other authors (Casal 2006; Costa-Pierce 2003; Courtenay 1997) have showed that, despite potential or observed benefits to human society, tilapia aquaculture and open-water introductions cannot continue unchecked without further exacerbating damage to native fish species and biodiversity. Their recommendations include restricting tilapia culture to carefully managed, contained ponds, although exclusion is preferred when it is feasible. Research into culture of indigenous species is also recommended. We are in agreement with this position and urge for tough prevention measures to avoid further and recurrent tilapia introductions into non-controlled systems in Hawaii. That requires public outreach actions to educate the population, especially of aquarists and aquaculturists, about the potentially severe negative impacts of fish releases in ponds and canals, but also stronger state regulation and enforcement of fish farming activities in the state. Signs should be posted at the Kawaiele site to warm and inform transients about the detrimental effects of fish introductions, and access to the site restricted as much as possible.

Finally, it is our understanding that seasonal variations in water level, temperature, salinity and pH, as well as in bird behavior, can significantly affect the efficiency and risks associated with the methods reviewed above. For instance, rotenone's rate of degradation is directly related to temperature and pH, while the presence of traps and nets during waterfowl feeding seasons may incur negative impacts to birds. The data available to us at the present indicates that site treatment should occur during the dry season (summer), when water levels are at their lowest. However, more data is required in order to develop specific predictions regarding the interactions between methods and seasonal conditions.

In conclusion, we recommend that after the base reconfiguration is completed:

- Die experiments should be conducted in order to determine the potential of ground water contamination with piscicides, especially through leaching;
- Seasonal data on water chemistry (T, S, pH, turbidity, alkalinity in $CaCO_3$ and organic demand) and site morphology (ponds' depth and dimensions) should be collected to determine the applicability of electrofishing as an auxiliary control method, to calculate

application rates for rotenone and potassium permanganate and to determine most suitable chemical application methods, treatment seasons and size and types of nets to be used;

- An experimental pond should be selected for pilot trials utilizing rotenone as the major eradication method for tilapia in the Kawaiele site, complemented if possible by netting and electrofishing.

Meanwhile, the following initiatives should be taken:

- Potential native species that could serve as biocontrol agent(s) should be identified and investigated; optimally, bioassays should be carried out to determine predation potential of these candidates on tilapia specimens;
- Consultation with State Dept. of Health should be initiated immediately to address the need for a general permit (to void the need for an NPDES permit) and with the Dept. Agriculture to address the registration of CFT Legumine (preferred rotenone formulation) or reregistration of Prenfish Liquid Toxicant (which's registration is due to expire in Dec. this year).

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Appendix 1: Supplementary Project Documents

MANAGEMENT OF TILAPIA IN THE MANA PLAIN CONSERVATION AREA, KAWAIELE SITE: PRELIMINARY PLAN (DRAFT)

Prepared by Joana Tavares (DAR's AIS Research Specialist) on June 10, 2008

Executive Summary: This is a first draft of a Preliminary Plan for the control of tilapia populations in the Kawaiele Waterbird Sanctuary, located in the Mana Plain Conservation Area, Island of Kauai, HI. The Kawaiele site is a wetland that was unintentionally created in the early 1990's when sand mining excavations reached the water table causing the flooding of the area. The site became a feeding and nesting ground for endangered and migratory waterbirds. These birds have had much of their natural habitat displaced by human occupation, thus the importance of recuperating this area. Later in that same decade, non-native invasive fish, including tilapia, were introduced to the site, causing significant negative impact on the vegetation that sustains waterbird populations. Now, as part of a multi-institutional effort initiated in 2004 to restore the encompassing Mana Plain Area, the tilapia populations in the Kawaiele site need to be eradicated, or at least controlled, so that the whole wetland recuperation is not jeopardized by this voracious grazer. The State of Hawaii Division of Aquatic Resources is one of the partners in this project, and has committed to administer the control of invasive fish populations in the Kawaiele site. This Preliminary Plan lays out a framework for AIS management as it applies to the Kawaiele Waterbird Sanctuary needs and characteristics.

Step 1: Establish overall goals and desirable outcomes for the management plan ☑

Per our discussions[3] and reading of the supporting materials[4], it is concluded that the ultimate goal of this project is to transform the Mana Plain/ Kawaiele Waterbird Sanctuary into a suitable habitat that can provide endangered and migratory waterbirds with the necessary resources for successful reproduction, including breeding and foraging habitats. Desirable outcomes are an increase in waterbird populations, as well as a general recuperation and enhancement of this environment, so that it can sustain native flora and fauna, and allow for associated environmental education and research initiatives.

Step 2: Identify major stressors, specific management objectives, and indicators ☑

Non-native invasive fish have been identified as major stressors in the Kawaiele Waterbird Sanctury as they displace native flora and fauna, negatively impacting waterbird foraging. Several non-native invasive fish, including more than one genus of tilapia (cf. *Oreochromis mossambicus*, cf. *Tilapia zillii*), as well as mosquitofish (*Gambusia affinis*), guppies (*Poecillia reticulate*) and mollies (*Limia vittata*) have been reported to occur in the Kawaiele site[5]. Preliminary results from an ongoing experiment have shown that the control and eradication of non-native fish, specifically of the tilapia from the Kawaiele site, will likely promote the growth of seagrass (*Ruppia* sp.), an important food source for waterfowl and coots[6]. Seagrass regrowth in the site is also predicted to offer suitable substrate for the development of invertebrate communities, which serve as food resources for the birds as well. Therefore, specific management objectives must include the reduction of tilapia populations to minimum levels possible and beyond threshold levels to be determined. Indicators of management success should be 1) regrowth of native seagrass and algae, 2) increase in populations of native fauna,

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[3] Two meetings: one at the FWS, on May 15, 2008 and the other at the Kawaiele Site/ DOFAW Baseyard, Kauai, on June 9,2008.

[4] "Conceptual Restoration Plan for the Mana Plain Conservation Area", prepared by Ducks Unlimited, Inc., (Draft), Oct. 2005; "Final Progress Report, Wetland Restorations at Mana Plain, Kaua'i, Hawai'i", by Adonia Henry, Ducks Unlimited, Inc., May, 2007.

[5] An aquatic survey of the Mana Wetlands, Kauai" by Troy Shimoda & Troy Shakihara, DAR, April, 2006.

[6] "Response of *Ruppia* sp. (seagrass) to Removal of Non-native Fish" Presentation handout prepared by Adonia Henry in collaboration with Kim Peyton, Jeffrey Herod, Wade Ishikawa, Thomas Kaiakapu and Christina Ryder, May 2008.

and 3) increase in the number of birds using the site as feeding and nesting grounds. Measurement units for each indicator are to be determined.

Step 3: Characterize the treatment area and target species

Biotic and abiotic conditions of the treatment area must be mapped and characterized. Target species should be identified so that candidate treatment methods can be reviewed in light of this information.

A *Preliminary Planning Questionnaire for the Tilapia Control in the Kawaiele Waterbird Sanctuary* was created in order to organize the process of gathering the necessary data **(see Appendix 1)**. The questionnaire should be answered to the best of our knowledge. If accurate measurements for the variables of interest are not available, best estimates and associated levels of uncertainty should be offered whenever possible. After the questionnaire has been answered, the costs and feasibility of collecting new data and improving accuracy of available estimates should be contrasted against the need for this information (indicated in the questionnaire). Data collection should then proceed accordingly.

Step 4: Identify possible treatment options for the treatment area and target species

Control and eradication of invasive species is a major scientific, technological and policy challenge for natural resources management. In general, eradication of established aquatic invasive species (AIS) is very difficult at best, and more often impossible. While few examples of success in complete eradication of AIS exist to this date, the establishment of long-term control of AIS populations seems to be a more frequent reality[7].

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[7] Some examples of successful control and eradication programs are the biocide treatment to control *Caulerpa taxifolia*, an invasive nuisance species of green algae discovered in a coastal lagoon in southern California (Withgott 2002), and the eradication of black-striped mussel *Mytilopsis sallei* from Australia's coastal waters through quarantine and chemical treatment of the entire affected harbor (Ferguson 2000). General reviews of invasive species management practices include (Bax et al. 2001; Mack et al. 2000; Wittemberg & Cock 2005)

Successful AIS control programs typically consist of the integration of different mechanical, chemical or biocontrol methods and measures of protection from reinvasion. In order to minimize risks and costs while maximizing prospects for control, integrated AIS control plans should scrutinize suitable combinations of methods considering the specific characteristics of the ecosystem to be treated and the biology of the AIS to be controlled. A literature review and contact with experts, and other managers should be carried out to identify best available scientific information that suits the treatment project.

Step 5: Estimate risks associated to treatment options

Risk is a function of likelihood of harm and the severity of the harm that results.

The goal of a successful AIS control plan is to effectively address the problems generated by the invasion while minimizing the risk of undesired outcomes.

Step 6: Identify applicable laws, regulations and authorities

Step 7: Design and conduct pilot project/ field experiment

This is a very important part of the process, as it allows for managers to test selected control techniques and application methods in real settings; make adjustments to procedures considering specific local constraints; train personnel that will work on the full-scale project; and whenever possible, develop ways to reduce risks identified in step 4. Permits and licenses will be necessary to carry out a pilot project.

Step 8: Assess risks, costs and benefits of the full-scale implementation and post-treatment monitoring program

A "Decision Index for Implementing the Control of Invasive Species" has been presented by (Bax et al. 2001) and is a useful tool to assist AIS management decisions. This tool consists of a cost-benefit equation that allows for the consideration of pros and cons of developing a proposed control plan. A simplified equation summarizes its rationale bellow:

$$\frac{Magnitude\ of\ the\ problem * likelihood\ of\ successful\ control}{(Magnitude\ of\ adverse\ results * likelihood\ of\ adverse\ results) + \cos t\ of\ results} = Support\ for\ control$$

The complete decision analysis tool is somewhat more complex, and allows for computations of ecological "costs and benefits", even when explicit economical values are not available. This is done by using developed indexes as a proxy for money values.

Step 9: Identify sources of funding

Step 10: Consult with stakeholders (i.e. relevant agencies, authorities, and local community)

The involvement of local communities through educational programs should start early in the process, preferably concomitant to the development of the project from step 1. The public should be made aware of the importance of the recuperation project, and also of the potential methods to attain the project's goals. At this point, however, it is important to organize an official forum with local community and organizations, as well as any relevant agencies and institutions so that overall support to the project is properly formalized through some sort of legal instruments (e.g. memorandum of understanding, statement of agreement, etc).

Step 11: Get permits and licenses to implement full-scale project

Step 12: Implement Full-scale Management Project

Step 13: Implement Monitoring Program

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Appendix 2: Communications with Researchers and Suppliers

Subject	RE: Request for information on Tilapia control
From	"Russell, John" <John.Russell@dpi.qld.gov.au>
Date	Monday, December 8, 2008 8:24 pm
To	Joana Tavares <joanat@hawaii.edu>

Hi Joana,

Thank you for your email. It is really good to make contact and exchange ideas with someone working with tilapias in other tropical areas. We have 2 species *(T. mariae and O. mossambicus)* that are causing concern in northern Australia. We have had a project working on the biology and ecology of feral stocks of these species including investigating the efficacy of some control measures. This project has been going for about 2.5 years. We are also using these biological/population data in a model to determine the likely effects of various control methodologies. We have used piscicides (rotenone) with varying degrees of success in lagoons, farm dams and, more recently, a small stream. As you are probably aware, *O. mossambicus,* because of its ability to stunt, can build up populations to very large numbers in small areas in relatively short periods of time. In one lagoon we removed about 10 tonnes of fish after a poisoning exercise. Depending on the size, configuration and other circumstances this may be an option for your brackish water ponds. We have also tried an integrated approach using predator control and mechanical removal through electrofishing in a small reservoir over about 18 months to control *O. mossambicus*. The predator we selected preyed on the juvenile O. mossambicus while we used monthly electrofishing to remove larger fish. The jury is still out on how successful this approach has been but we have certainly driven the population down to a point where say 7000 seconds of ontime electrofishing effort might yield only between 5 and 30 tilapia. We have some ideas for trapping which we hope to trial next year.

I would be interested to know what you have been planning and if you have found any particular control methods promising. It is interesting that O. mossambicus are infesting brackish water ponds - while we do find them here occasionally in brackish water areas they seem to prefer freshwater drains, rivers and impoundments. We were initially concerned because of reports from some of the Pacific islands of tilapia being found around inshore reefs that they might colonise areas on the Great Barrier Reef but that doesn't appear to have happened (yet). Also I've heard that there is a cichlid (possibly tilapia?) that is found in reasonably large numbers in marinas on one or more of your islands - do you know if this is correct?

If you have any publications or web sites related to tilapia control or issues in your area I'd be most interested to know about them.

Regards

John

From: Joana Tavares [mailto:joanat@hawaii.edu]
Sent: Friday, 5 December 2008 8:46 AM
To: Russell, John
Subject: Request for information on Tilapia control

Dear Mr. Russell,

Aloha,
My name is Joana Tavares and I work with Aquatic Invasive Species in the State of Hawaii. We are currently considering various methods to eradicate/ control tilapia infestations (*Tilapia zillii*, *Oreochromis mossambicus*, and possibly others) in brackish water ponds here in Hawaii. I came across some articles online that mention your work with the control of tilapia and was wondering if you would have any information you could share with us on the topic; specifically, we would sincerely appreciate any data on the efficiency of electrofishing and netting attempts you may have.
Thank you,
Joana

****
Joana Flor Tavares
Aquatic Invasive Species Research Specialist
State of Hawaii's Division of Aquatic Resources
1151 Punchbowl Ave., Room 330
Honolulu, HI 96813
****

Subject	**Re: Cost Estimate for Rotenone Treatment (DAR Hawaii)**
From	Ruth Fisher <ruth.fisher1@verizon.net>
Date	Wednesday, January 28, 2009 4:34 am
To	Joana Tavares <joanat@hawaii.edu

Good morning! Here's what I learned from the traffic person:

"It's difficult to get a rate to Hawaii. With our other customers, we get the rate to the West Coast pier (in this case $235.70) and then ship collect from CA to HI."

I hope this helps.

----- Original Message -----

From: Joana Tavares

To: ruth.fisher@prentiss.com

Cc: sarap@hawaii.edu

Sent: Friday, January 23, 2009 5:45 PM

Subject: spam: Cost Estimate for Rotenone Treatment (DAR Hawaii)

Dear Ruth Fisher,

Thank you for returning my call.

Here are the details of our tilapia eradication plan:

We intend to treat approximately 60 acre-feet with Prenfish Toxicant Liquid (5%). I believe that for complete kill of tilapia we would then be looking at 60 gallons, correct?

Could you please send us an estimate of cost for this amount of this product, including the cost of shipment to Honolulu-HI?

Also, we would appreciate if you could also send us an estimate of the price for the same amount of CFT Legumine™ Fish Toxicant.

Aloha!

Joana

****

Joana Flor Tavares

Aquatic Invasive Species Research Specialist

State of Hawaii's Division of Aquatic Resources
1151 Punchbowl Ave., Room 330
Honolulu, HI 96813
****

Subject	**Re: Cost Estimate for Rotenone Treatment (DAR Hawaii)**
From	Ruth Fisher <ruth.fisher1@verizon.net>
Date	Monday, January 26, 2009 9:15 am
To	Joana Tavares <joanat@hawaii.edu>

Hi, Joana. Pricing for Prenfish in 30's is $58.95/ga plus freight. Pricing for CFT Legumine is $76/ga plus freight. Will send you freight costs as soon as available. It was good talking with you.

----- Original Message -----

From: Joana Tavares
To: ruth.fisher@prentiss.com
Cc: sarap@hawaii.edu
Sent: Friday, January 23, 2009 5:45 PM
Subject: spam: Cost Estimate for Rotenone Treatment (DAR Hawaii)

Dear Ruth Fisher,

Thank you for returning my call.

Here are the details of our tilapia eradication plan:

We intend to treat approximately 60 acre-feet with Prenfish Toxicant Liquid (5%). I believe that for complete kill of tilapia we would then be looking at 60 gallons, correct?

Could you please send us an estimate of cost for this amount of this product, including the cost of shipment to Honolulu-HI?

Also, we would appreciate if you could also send us an estimate of the price for the same amount of CFT Legumine™ Fish Toxicant.

Aloha!

Joana

****

Joana Flor Tavares
Aquatic Invasive Species Research Specialist
State of Hawaii's Division of Aquatic Resources
1151 Punchbowl Ave., Room 330
Honolulu, HI 96813
****

Subject	Re: Request for information on the use of detonation cord
From	Amber Rossi <arossi@dfg.ca.gov>
Date	Wednesday, February 11, 2009 10:29 am
To	Joana Tavares <joanat@hawaii.edu>

Hi Joana,
We found detonation cord not to be a successful means for eradication during the pike project. Here is a link to our website, which contains documents relating to the detonation cord use at Lake Davis including our project results. http://www.dfg.ca.gov/lakedavis/det_cord.html I hope that you find this useful.
~Amber

Amber S. Rossi
District Fisheries Biologist: Plumas/Sierra County
California Department of Fish and Game
P.O. Box 1858
Portola, CA 96122
Phone (530) 832-4068
Cell (530) 520-4753
Fax (530) 832-9706
arossi@dfg.ca.gov

>>> Joana Tavares <joanat@hawaii.edu> 2/10/2009 5:23 PM >>>
Aloha!
I am a researcher for the Division of Aquatic Resource of the State of Hawaii and would like to know if it would be possible for you to provide me with any reports on the experiments the DFG did with detonating cord to kill Northern Pike in Lake Davis. We are conisdering various methods to control invasive fish here in Hawaii, and this information would be most valuable for us.
Thank you,
Joana

****
Joana Flor Tavares
Aquatic Invasive Species Research Specialist
State of Hawaii's Division of Aquatic Resources
1151 Punchbowl Ave., Room 330
Honolulu, HI 96813
****

Subject	Re: Request for Fintrol Specimen Label

From	mkromeo@att.net
Date	Sunday, February 1, 2009 8:14 pm
To	Joana Tavares <joanat@hawaii.edu> , aquabiotics@gmail.com

Attached is the current label.

1 unit of fintrol treats 7.5 acre-feet at 5 parts per billion, which kills scalefish with water temperature above 60 degrees and pH < 8.0. 50% more Fintrol is needed for temperatures below that, or pH above 8.5.

60 acre-feet/7.5 acre-feet = 8 units. If I sell it at the current price of $400/unit, that is $3200. I am currently out of Fintrol and do not know when I will have more, but I'm working on developing a new supplier.

Sincerely,
Mary Romeo
-------------- Original message from Joana Tavares <joanat@hawaii.edu>: --------------

Hello Mrs. Romeo,
I was wondering if you could send us the old Fintrol label and also an estimate of cost to treat about 60 acre-feet of water with Fintrol.
Thank you,
Joana

****

Joana Flor Tavares
Aquatic Invasive Species Research Specialist
State of Hawaii's Division of Aquatic Resources
1151 Punchbowl Ave., Room 330
Honolulu, HI 96813

****

----- Original Message -----
From: mkromeo@att.net
Date: Thursday, December 4, 2008 4:12 pm
Subject: Re: Request for Fintrol Specimen Label
To: Joana Tavares <joanat@hawaii.edu>

> Fintrol is going through reregistration with EPA. I need
> to design and get a new label approved. Do you want to
> wait until next year's label is available, or do you want an old one?
>
> Sincerely,
> Mary Romeo, President
> -------------- Original message from Joana Tavares
> <joanat@hawaii.edu>: --------------
>
>
> Dear Mr. Romeo,
>
> Greetings,
> I work with the control of Aquatic Invasive Species in the State

> of Hawaii and would like to receive more information about
> Aquabiotics Fintrol (Antimycin A) Fish Toxicant. Specifically, I
> would like to receive a current version of this product's
> Specimen Label.
> Our Division is reviewing various methods to be used in future
> invasive fish control efforts and we would like to be able to
> consider Fintrol as well.
> Thank you so much for your time,
> Joana Tavares
>
>
> **
> Joana Flor Tavares
> Aquatic Invasive Species Research Specialist
> State of Hawaii's Division of Aquatic Resources
> 1151 Punchbowl Ave., Room 330
> Honolulu, HI 96813
> ** null

Subject	Fw: Rotenone & Antimycin - tuition
From	Jim_Brooks@fws.gov
Date	Thursday, February 12, 2009 6:31 am
To	joanat@hawaii.edu
Cc	Chris_Horsch@fws.gov , Gary_Schetrompf@fws.gov , dpropst@state.nm.us , June_McIlwain@fws.gov , So_Lan_Ching@fws.gov

Hi Joana,

I am one of the instructors for the upcoming piscicide class in Hawaii and wanted to respond to your inquiry regarding rotenone neutralization. I've also copied the other course instructors and course leader in case they have any thing to add.

The short answer is that until rotenone is re-registered, you should use the existing label on the product and follow those directions. The RED for rotenone identifies what must be on the new label and in any SOP manual developed as a part of re-registration. But, it is not to be used for any project until re-registration is complete. But you are right in that it is not clear on the RED if there is a distinction between standing and flowing water and how that will be treated in the final registration packet. My read is that all water will have to be treated, but how is another issue. None of the rotenone types, as currently registered, require (just describe method for) that you neutralize with $KMnO_4$ unless you wish to limit downstream impacts in a lotic system. Obviously we want to limit those impacts so we neutralize to restrict impacts to the intended project area.

Normally, lentic waters are not neutralized unless the water is to be released and in that case you would set up a neutralization station at the release site and neutralize the flow as it exits the lake or pond. You can neutralize in a lentic environment, but rotenone degrades naturally, usually within 1-4 weeks and depending upon the type of environment (temp, pH, organics, wind/wave, etc.) treated. Human re-entry to such a treated area, by current label directions, is not restricted. However, once re-registered a re-entry restriction of 3 days will be required and it will also include closure of the project area to public access. The existing SOP manual (of which you'll get a copy at the class) is consistent with what I have said above and if you need to look at it in the meantime, it can be found as a pdf file on the American Fisheries Society website under the tab for Rotenone Stewardship. The RED also references use of a SOP manual and it will not be the current manual located on the AFS website. A new SOP manual will have to be prepared as part of re-registration.

Beginning on page 116 of the current SOP manual is a 2-3 page section describing neutralization procedures. Also listed is the supplier for the 5% aqueous solution. Granular forms can be found at most of the industrial and ag chemical suppliers. We have bought in smaller quantities (< 500 lbs.) of the granular from Argent Chemical in the past, but I have not purchased any lately and I'll do some checking and let you know what I find out (probably later today or tomorrow).

We'll cover neutralization procedures in the class, but our emphasis will not be on what is required once rotenone is re-registered (not before 2010).

Hope this helps and let me know if you need something else or want to talk. I'll get back to you on potential suppliers of KMnO4.

Jim Brooks
U.S. Fish and Wildlife Service
New Mexico Fish and Wildlife Conservation Office
3800 Commons Avenue NE
Albuquerque, NM 87109
Office: 505/342-9900, ext. 102
FAX 505/342-9905
Cell: 505/917-1117

Appendix 3: Preliminary Cost Analysis

(To be completed)

	Costs (US$)	
	per ac-ft	total volume
Piscicide		
CFT Legumine (preferred product)	76.00	5,000
Prentiss Prenfish Liquid Toxicant	58.95	4,000
Rotenone Fish Toxicant Powder	26.42	1,700
Fintrol	213.00	14,000
Freight (expected to be about the same for liquid rotenone, lower for Fintrol and higher for Rotenone Powder)		~400-1,000
Certified Applicator's Salary		
Personnel*		
Electric Trolling Boat (1)		1,500
Non-motorized Boats (Dinghy/ Skiff)(4)	-	2,500
Safety Equip. (x personnel)	100	100
Dripping station (5)		
Mixing Station(1)		
Equip. transp. to site		
Potassium Permanganate (for neutralization)	< 0.4	180
Shipping of Potassium Permanganate		
Personnel* for neutralization operation		
Application equipment for neutralization		
Licenses and permits		
Specific Public Meetings/ Outreach		
Warning signs/ site vigilance		
Netting		
Nets	~350 (+ shpg)	1,000 (+shpg)
Boats		
Personnel*		
Electrofishing		
Transport of electrofisher-boat to site		
Protective gear and equipment		
Planning and preparation (logistics)		
Personnel*		
Blasting/ Explosives		
Certified Operation Supervisor		
Primacord (detonation cords)		
Divers (to prepare site/ set cords under water)		

Protective gear and equipment		
Planning and preparation (logistics)		
Personnel*		
Specific Public Meetings/ Outreach		
Licenses and permits		
Dead fish removal		
Nets		
Transport of carcasses to disposal site		
Boats		
Personnel*		
Planning and preparation (logistics)		
Permit for disposal site		
Generics		
Public Meetings		
Posting of information signs		
Video recording of operation		
*Personnel Costs include salary, per-diem and transportation to site		

Appendix 4: Specimen Labels