TECHNICAL NOTE

USDA NATURAL RESOURCES CONSERVATION SERVICE PACIFIC ISLANDS AREA

Biology Technical Note No. 21

Practices to Enhance Native Wildlife Habitat on Wetland Taro Farms

PURPOSE

To provide a background on practices that enhance native wildlife habitat in wetland taro or *kalo* (*Colocasia esculenta*) systems and support sustainable farming.

WHY MANAGE WILDLIFE HABITAT ON A TARO FARM?

Wetland taro is cultivated in flooded terraces typically carved from rich alluvial soils. The resulting expanse of shallow open water in this productive zone attracts a variety of wildlife. Five Listed Endangered (LE) waterbirds, the Hawaiian Duck (Koloa), Hawaiian Coot (Alae keokeo), Hawaiian Moorhen (Alae ula), Hawaiian Stilt (Aeo), and Hawaiian Goose (Nene) and at least 25 species of migratory waterfowl and shorebirds use taro farms. Associated waterways are habitat for native aquatic species such as the striped mullet, hihiwai (mollusk), and mountain opae (shrimp). All 5 endemic Hawaiian oopu (gobies) are found in Hanalei Valley and Waipio Valley, the largest taro cultivation areas in the state.

Likewise, there are several noxious species in taro systems that threaten native wildlife, taro production, and watershed functional values. These include: feral ungulates, mammalian predators, apple snails, feral ducks, aquatic weeds (e.g., parrot's feather), and taro pathogens such as *Pythium* root rot. Control of noxious species and management for Hawaiian waterbirds are possible through the use of wet fallow periods.

Hawaiian Moorhen **© Photo by J. Jeffrey**

Taro cultivation is an agricultural tradition of the Hawaiian people and considered a vital component of the ahupua`a (traditional land management system that extends from mountains to sea). Taro farming lends itself to a systems approach to addressing conservation objectives. Therefore, it is expected that measures applied to taro farming to benefit wildlife can address other resource concerns.

Taro is a member of the Philodendron family (Araceae) farmed in upland or wetland conditions for its corm and leaves. In 2003, wetland taro represented 390 of 420 acres in taro production. Of the 390 acres reported, 64% was located on Kauai, 14% on Hawaii, and 22% on Oahu, Maui, and Molokai. The State of Hawaii produces 6.1 million lbs of taro worth $3.1 million per year on average. For information on the taro cycle, practices, and products see Appendix A and References.

Fossils indicate that today's Hawaiian waterbirds have been in Hawaii for at least tens to hundreds of thousands of years. Some believe that Polynesian navigators interpreted the migratory cycle of the Pacific Golden-Plover (Kolea) to mean undiscovered lands north, leading to colonization of Hawaii. Native fish and wildlife occupy an important aesthetic, cultural, and ecological niche. However, the fauna that remain are a remnant of the diversity of species that once inhabited these islands. Conservation practices suggested here are intended to be compatible with farm goals, and brighten the future of these remarkable species.


Hanalei NWR, Kauai Photo by T. Erickson

In accordance with landowner objectives, management treatments should address the habitat elements limiting wildlife habitat potential. Several approaches may apply. Possible treatments are addressed in the following practice standards (NRCS Field Office Technical Guide):

- Wetland Restoration (657)
- Wetland Enhancement (659)
- Wetland Creation (658)
- Wetland Wildlife Habitat Mgmt. (644)
- Upland Wildlife Habitat Mgmt. (645)
- Shallow Water Development and Management (646)

This technical note gives the purpose and background information for Practice 646, Shallow Water Development and Management.

WHAT IS SHALLOW WATER DEVELOPMENT AND MANAGEMENT?

This practice is intended to assist farmers in retaining, developing, or managing shallow water on agricultural lands, depressional areas, and wetlands in order to provide a mosaic of open water and native or naturalized wetland plants for loafing (resting), foraging, and breeding by resident waterbirds and other aquatic wildlife and winter habitat for migratory waterfowl and shorebirds.

Practice 646 can be applied to existing or rehabilitated patches or new wildlife impoundments. Consider remote wet areas, marginal pastures or farmlands, or other depressional areas where water can be impounded and regulated.

On the ground construction, management, and conservation crop rotation can benefit both the farm and native wildlife. Under this practice, for instance, historic taro patches could be restored and managed for wildlife, or wildlife and taro as part of a rotation. In this case, water and vegetation management for birds would emulate a wet fallow period (typically maintained at a mosaic of <50-75% plant cover). Benefits include:

Wildlife Benefits:
- Add choices of habitat types
- Increase foraging resources
- Increase breeding opportunities
- Offer resting and feeding areas with less human disturbance

Farm Benefits:
- Rest fields
- Regenerate competitive soil microbes
- Help break disease and pest cycles
- Increase diversity of organic matter and microbes in soil
- Incorporate nutrients into soil
- Waterbirds reduce weed seed, crayfish, apple snails, and other pests
- Nutrients distributed via foraging birds and plant roots
- Reduce management costs

General criteria that can benefit both taro farming and native wildlife are discussed in the following 5 sections:

1. CONSTRUCTION
2. WATER LEVEL MANAGEMENT
3. VEGETATION MANAGEMENT
4. BREEDING CONSIDERATIONS
5. NUTRIENT AND PEST MGMT.

CONSTRUCTION

Fencing. Dogs are major predators of waterbirds and small livestock. Feral and domestic ungulates (e.g., pigs, goats, horses) can trample nests and young and damage dikes and crops. Fences can exclude large mammalian predators and ungulates and control human access. The fence standard and specification (382) should be used to determine the kind of materials and fence needed to exclude target species.

Erosion control. Dike washouts due to crayfish burrows are a common problem on taro farms. Weed control along banks is a major expense. Permeable liners can reduce management costs for dike and weed maintenance, and decrease sedimentation into waterways. Installation of a permeable lining along critical areas can control crayfish damage, weeds, and erosion problems, improve water quality, and benefit the fauna of receiving waters.

Farmers who have installed weed matting along critical areas (e.g., lower banks near outflows) have noted a substantial reduction in crayfish burrowing and weeds. See Practice 646 Specifications for more information.

Irrigation water conveyance, underground pipelines, vegetated waterways, livestock exclusion zones, and other sediment and nutrient control features can be included in the conservation plan for water quality. Basins and waterways can be designed to accommodate native wildlife.

Some farms designate small patches closest to the outlet (to the stream) as "treatment cells." The patches contain plants that trap sediment and assimilate nutrients before the water re-enters the stream. Outgoing waters can also be used to irrigate upland crops.

However, these techniques cannot replace good soil conservation practices that keep soil in the patch. At a minimum:

1) Install (and operate) water control devices that allow patch inlets and outlets to be blocked during operations in flooded conditions. Allow suspended solids and nutrients to settle for several days before opening any outlets.
2) Install drainpipes far enough above patch bottom to minimize soil loss, but low enough to drain patch completely.
3) Line impact areas (in/outlets) with rocks or bricks to avoid erosion.
4) Block primary intakes during flood conditions.
5) For more info on best management practices see CTAHR (1997).

Goby-friendly outlets. Consider outlets that can improve survival and recruitment of Hawaiian oopu. Outlets completely above the water surface allow gobies to bypass taro patches during upstream migrations. Predation pressure on gobies that enter taro patches is believed to be elevated due to higher densities of introduced tilapia, mosquito fish, and crayfish. Exotic fish also carry diseases and parasites to which endemic gobies are not resistant.

WATER LEVEL MANAGEMENT

Water levels can be managed to maximize resources to LE and migratory waterbirds and increase their chances of success for breeding and transoceanic migration. Control of water duration and depth with water control structures or other measures allows water levels to be adjusted or extended through drier months for LE chicks to fledge (obtain flight).

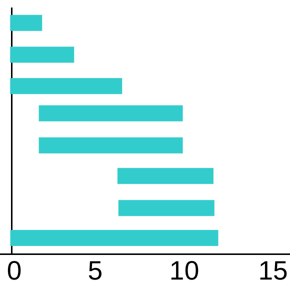
For migrants and LE Nene and Koloa, shallow water areas should be flooded from fall to spring and drawn down during the summer to promote growth of desirable food plants that will benefit wildlife. After seed producing plants have matured, and during the fall migration, the area should be flooded to a depth of 1-12 inches. The flooded food plants provide excellent resting and feeding areas for dabbling ducks that tip to feed, such as the shoveler, pintail, and teal. The optimum feeding depth for these ducks is 4-10 inches (Figure 1).

In early spring, freshly tilled patches with shallow water (mudflats to 4 inches of water) are beneficial to shorebirds, such as Kolea and tattlers (Ulili) on their migration north. In late spring, these sparsely vegetated mudflats provide forage for LE Hawaiian Stilt pairs and chicks (<1-2 inches water depth).

Subsequently, partially vegetated patches flooded to a 6-8 inch water depth can provide habitat for LE Hawaiian Coot, Hawaiian Moorhen, and native Black-crowned Night-Heron (Aukuu). The hydroperiod (seasonal hydrology) should be extended through peak breeding months (spring or summer depending on location). Maintain soil dry for at least 4-8 weeks to improve soil conditions. Maintenance and drawdowns (dewatering) can occur outside peak breeding seasons (Figure 2, Appendix B).

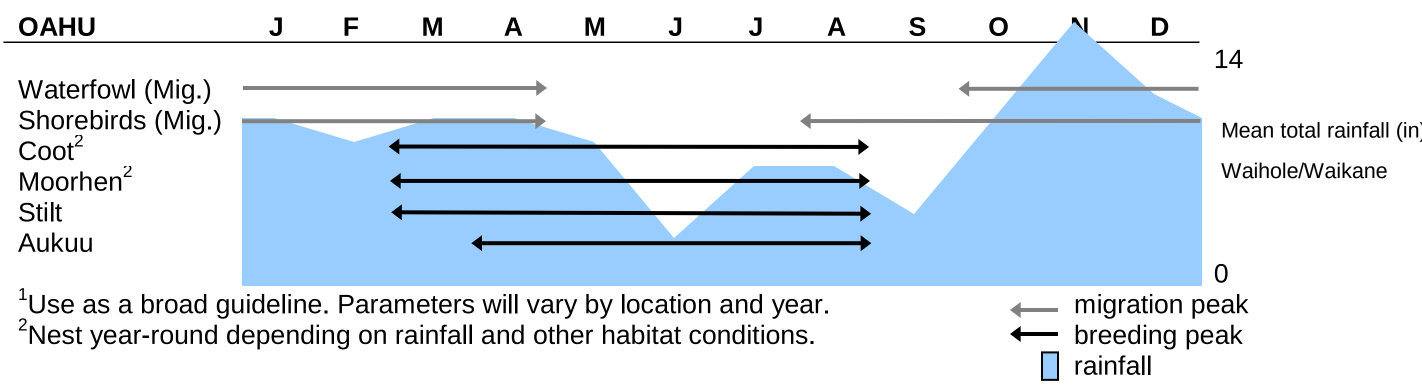
A constant cool water source (<78° F) is required for taro production; whereas, a wider range of temperatures is acceptable for wildlife habitat.

Figure 1 Mean water depths for shallow water impoundments and primary foods of Hawaiian waterbirds



	Water depth (in)	Vertebrates	Invertebrates	Seeds	Browse
Shorebirds (Mig.)	0-2		X		
Stilt	0-4		X		
Aukuu	0-6	X	X		
Waterfowl (Mig.)*	2-10		X	X	
Koloa	2-10		X	X	
Coot	6-12		X	X	X
Moorhen	6-12		X	X	X
Nene	0-12			X	X

Figure 2 Annual rainfall and migration and breeding peaks of Hawaiian waterbirds, Oahu example[1]



[1]Use as a broad guideline. Parameters will vary by location and year.
[2]Nest year-round depending on rainfall and other habitat conditions.

VEGETATION MANAGEMENT

There are 2 ways to provide quality wildlife foods through vegetation management: 1) allowing natural regeneration of specific wetland plants and 2) planting a crop for wildlife.

Advantages of allowing natural regeneration of specific wetland plants over planting crops are:

- Minimizes management costs, some weed control is needed
- Attracts greater diversity of wildlife
- Provides foods with greater nutrient value
- Works on marginal crop sites
- Production is less influenced by weather

Advantages of planting wildlife crops are:

- Can increase total energy production for waterbirds
- Does not require as precise water control
- Easier to control undesirable plants

Natural regeneration of wetland plants. Plants such as wild rice, smartweeds, sedges, and spikerushes can be grown from the seed bank through water level manipulations to germinate and produce an abundant source of quality food for waterbirds. These beneficial native and nonnative species are typically found in the seed bank of most low elevation wetlands.

Sedge (C. polystachyos)

L. Crago

Water smartweed (& Koloa)

K. Uyehara

Drawdowns are necessary for plants to germinate. Slow drawdowns (2-3 weeks depending on patch size) are more desirable for plant establishment and wildlife use. A gradual decline in water levels can concentrate fish and invertebrate prey, which are important protein sources for waterbirds (Figure 1). Naturally occurring wetland plants, properly managed, provide more seed and plant parts, higher invertebrate diversity than planted wildlife crops. Plants with more divided leaves provide more attachment points for invertebrates.

Experiment with naturalized wetland plants in the first year to see which ones germinate. Consider seed bank when determining food species to manage for (Appendix C). Often, the seeds and timing and type of drawdown will determine the species composition. In general, slow spring drawdowns produce smartweeds and sedges, while summer drawdowns produce grasses and composites (depends on location). The timing and extent of the drawdown should be varied year to year to maintain productivity and a diverse plant community. Contact the State Biologist for assistance with plant ID.

Annuals (plants that complete their life cycle within 1 year or season) have the highest seed production. Therefore, to maintain the site in early successional species (mostly annuals) and to control undesirables, in addition to annual drawdowns, it is best to dewater the site and disc every 1-2 years or prepare the patch for taro production. Most fields become unproductive if they are not disked regularly.

Flooding the site slowly allows new areas of food to become available each day at the preferred water depth as the water is rising.

Hawaii has a year-round growing season, and taro is typically farmed in high rainfall zones. The requirement for management and maintenance will vary by location, weather, and year. There is no recipe. Adaptive management (continually improving the practice by learning from the outcome) is essential to succeed in sustainable, biologically integrated farming systems. See Appendix D for case examples.

Planting waterbird food crops. Consider a rotation that alternates wildlife food crops with taro. The wildlife crop can be incorporated into the fallow period. On the mainland, low-growing varieties of small grains and legumes such as clovers, barley, wheat, and millets are recommended for waterfowl. Wetland crops (e.g., rice) benefit a wider range of wetland fauna.

Bi-cultures are preferred over monocultures for wildlife to offer some structural and plant diversity. Wildlife crops should be grown in a manner that makes seeds and other plant parts available to birds for forage and nesting.

Some species used for cover crop, green manure, or conservation cover are also food for wildlife. For example, Nene frequently graze on Bermuda and Bahia grass. Both grasses are recommended as groundcovers to control erosion and improve water quality, but may be invasive under certain conditions. Moorhen have been observed foraging on invertebrates associated with azolla. Azolla and legumes add biomass and nitrogen to the soil. The Hawaiians traditionally used kukui and hau leaves, and spikerushes for green manure.

Consider native species valuable to wildlife that may be less aggressive in a taro patch (Appendix C). Waterbirds are opportunistic feeders that utilize both native and nonnative species. They generally seek the structure (e.g., cover, nesting material) and function (e.g., nutrition, energy) of plants rather than species. The plant species, in part however, dictates nutritional value and structure.

Use extreme care during plant selection to avoid introducing noxious species to the area. Contact the State Biologist, Plant Materials Specialist, or the Cooperative Extension Service (CES) for guidance on appropriate cover crops and green manures that can be beneficial to wildlife in the project area.

Riparian Buffers. Protect freshwater and marine resources from siltation and non-point source pollution by establishing a vegetative buffer. For example, herbaceous buffers (393) on ditches and riparian forest buffers (391) on streams help protect farms from scour erosion, regulate water temperature, and improve microhabitats for native stream organisms.

BREEDING CONSIDERATIONS

Farm practices can have a positive or negative effect on wildlife depending on the timing and duration. Some practices that overlap with critical nesting or staging (pre-migration) periods, for example, can have a significant impact on wildlife behavior. Birds are more sensitive to sudden changes in habitat conditions during these periods.

For example, coots and moorhen nest over or close to water and stilts on mudflat shoals and shorelines. Weed maintenance and water level fluctuations could result in nest desertion or flooding. On the other hand, when birds are not breeding, weed control is a beneficial farm practice because plants are maintained at a mid-successional stage. Without weed control, patches become overgrown within 4-6 months and are of little value to wildlife.

Koloa and coots nest in herbaceous bank or upland vegetation, where weed control could result in nest abandonment or destruction. Koloa hens often lead broods (ducklings) overland to adjacent wetlands at the first sign of danger, exposing young to unfamiliar territory and predators. Therefore, weed maintenance of areas that may support breeding birds should be scheduled outside peak breeding times. See Table 1 and Figure 3 for typical nesting sites.

Coots and moorhen sporadically forage on taro shoots. According to farmers and biologists in Hanalei, Kauai, this behavior is uncommon but generally occurs prior to breeding in extremely dry years. Birds could be seeking calcium in taro when regular sources (snails, crustaceans, insects) are unavailable (e.g., other habitats not meeting nutritional requirements or Niihau ephemeral lakes are dry). Wet fallows (or restored wetlands via WRP), well managed, should provide alternate food resources to meet annual cycle needs of birds and reduce feeding on taro.

Nene are upland browsing grazers and benefit from mowing and grazing practices. Nene often forage on the tender shoots of grasses and forbs, nest in areas with herbaceous and sparse woody cover, and use water bodies for swimming and predator avoidance.

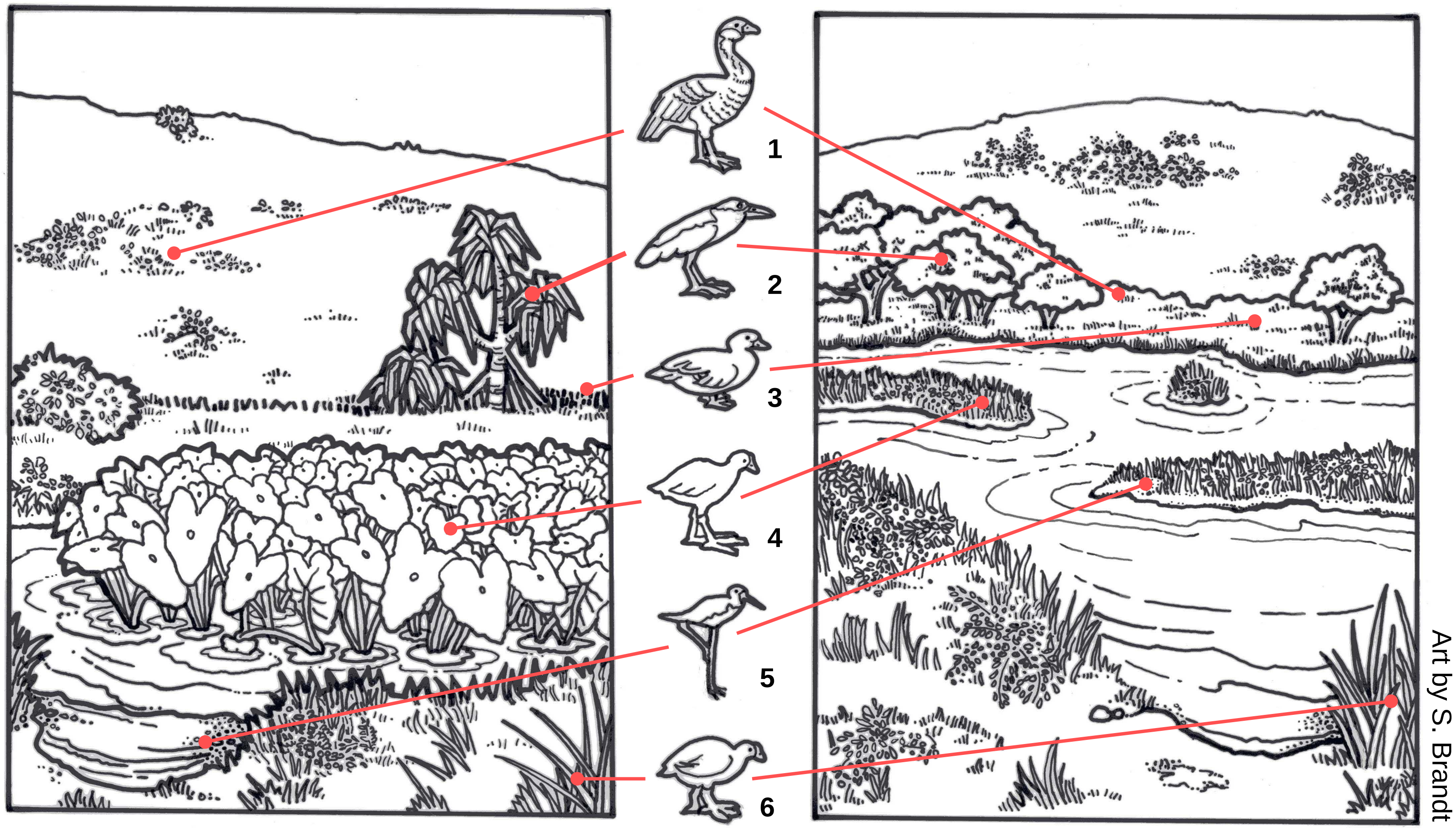
Consider creating or enhancing upland nesting areas for Koloa and Nene. Marginal or uncultivated farmland could serve this purpose. Large contiguous areas away from human activity are better than small areas near human activity. Manage noxious species to create a mosaic of cover types and control predators (Table 1).

Table 1 Duration of breeding and typical nesting habitats of Hawaiian waterbirds

	Duration (no. of days)				
Species	Incubation	Fledgling	Total (max)	Nesting Habitat Taro Farm	Nesting Habitat Marshland
Nene	29-32	70-98	130	Tall grass in uplands or under vegetation along ditch banks	Ranges widely, mix of herbaceous and woody cover in uplands
Koloa	28-30	~65	95	Vegetated banks or other herbaceous vegetation in uplands near water	Herbaceous vegetation in uplands near water
Coot	23-27	60-70	97	Taro plants or other emergent vegetation over or adjacent to water	Emergents over or adjacent to water
Moorhen	19-22	40-50	72	Taro plants >4 months old or other emergent vegetation over or adjacent to water	Robust emergents over or adjacent to water
Stilt	25	28-42	67	Edge of dike on bare soil or mudflat in paddy	Sparsely vegetated mudflat
Aukuu	24-26	42-49	75	Branches of trees near water	Same

Studies show that even passive human activities (e.g., walking, birdwatching, fishing, driving) negatively impact breeding, feeding, and migrating birds. February to April is a critical period when shorebirds are molting and building fat reserves for migration north to breed. Recently a Kolea was documented flying from Oahu to Alaska nonstop about 2,800 miles within 70 hours. If frequently disturbed, migrants cannot build adequate fat stores and may be forced to fly underweight. Consequently, these birds may not make it to their breeding grounds.

Figure 3. Where do waterbirds typically nest?



Taro Farm

Marshland

1 Nene	**4 Moorhen**
2 Aukuu	**5 Stilt**
3 Koloa	**6 Coot**

By providing undisturbed feeding and roosting areas, farmers are contributing to successful breeding, whether it occurs on or off the farm. Buffer zones, alternate pathways, and being aware of these concerns will greatly improve habitat conditions.

See Practice 646 standards and specifications for additional breeding guidelines.

NUTRIENT AND PEST MANAGEMENT

Nutrient Management. Coots, moorhens, and stilts that nest over or close to water are particularly vulnerable to water level fluctuations. Nest desertion and inundation can result from fluctuations needed to apply fertilizer. In taro production areas, consider the type and form of fertilizers and adopt methods to reduce the rate and frequency of applications and the need for drawdowns when waterbirds are breeding. A fallow rotation can restore soil fertility and reduce fertilizer requirements and costs.

Pesticides. There are fungicides, herbicides, and insecticides approved for use on taro. Nearly all products have use restrictions in flooded conditions and require draining, shielding (controlling drift), or waiting periods. For example, Roundup WEATHERMAX™ is currently permitted on dikes and banks of wetland taro, and in dry taro patches. Herbicides are generally less toxic to wildlife than insecticides.

A secondary effect of herbicides can be habitat alteration. The loss of vegetative cover, seed producing plants, and insect habitat may cause birds to move to other feeding grounds and lower reproductive success. The long-term effects of increased exposure of wildlife to pesticides are uncertain. Pesticide regulations change frequently. For up-to-date regulatory information, contact Hawaii Department of Agriculture's Pesticides Branch at (808) 973-9401. For questions on application, contact the Pesticide Risk Reduction Education Program (Pesticide Applicator Training, UH) at (808) 956-6007.

Weed management. Timing is key in habitat weed management. Schedule large weed control projects during nonbreeding periods. Take care to prevent waterbird mortalities during routine maintenance. Reduce the amount and frequency of manual weeding and pesticide applications when possible, especially near water where applications can reduce invertebrates. Less intense weed management enhances wildlife food, cover types, and reduces chances of exposing young to predators, bad weather, or toxicants. Methods that allow some growth of plants valuable to wildlife and reduce long-term weed management costs are favorable. Less human activity in taro patches may increase plant vigor.

Marsh fleabane

Water lettuce (& apple snail)

L. Crago

Undesirable plants to control include California grass, honohono grass, Job's tears, papyrus, parrot's feather, water lettuce, waterweed, and woody species such as marsh fleabane.

Many farmers are opting for use of mowers and bushcutters instead of herbicides. Mechanized control decreases ongoing herbicide expense, promotes a healthier farm, and decreases negative water quality effects off site.

Crayfish control. Crayfish burrowing activities can breach dikes, increase sedimentation, and degrade water quality downstream.

One farmer has integrated trapping, liners on lower banks (where activity is high), and regular inspections. Inexpensive traps can be made with wire mesh or plastic bottles. Oily fish parts can be used for bait.

Crayfish are nocturnal omnivores, breed year-round in Hawaii, and 1 female produces 50-600 eggs per cycle. No pesticides are approved for use on crayfish. Crayfish eradication is unlikely due to ongoing immigration; however, integrated pest management should keep populations low, limit dike damage, improve water quality, and provide a food source for the farmer. Farmers may supplement income through crayfish and apple snail culture. Hawaiian waterbirds are important predators of small crayfish and apple snails.

Apple snail control. The apple snail problem is widespread in Southeast Asia and the Pacific. They are prolific feeders and breeders. Female snails lay 200-500 eggs per cluster and can lay clusters every 2 weeks. An adult snail lives 2-5 years depositing over 5,000 eggs in a year. Snails forage on algae, taro, and a wide range of aquatic plants. Large snails and eggs are not known to be eaten by waterbirds. Small snails are a food source for waterbirds. However, given the voracious feeding habits of apple snails, it is likely that high densities of apple snails can alter species composition in impoundments and indirectly affect the food base for waterbirds. Apple snails have been implicated in the decline of native species in Southeast Asia.

Prevent new invasions. New ditches and impoundments should be designed so that they do not create new corridors or sites for apple snail invasion. Apple snails colonize new areas via moving water. Avoid flows that link patches with apple snails to those without.

Farmers have devised many creative ways to screen and trap snails such as using swales and chicken feed, or neem and papaya extract. Farmers use multiple techniques to keep snail populations manageable. See Cowie (2002) for apple snail treatments. There are currently no molluscicides approved for use on apple snails. Snails are collected by hand and destroyed. From 1994-1996, there was a Special Local Need (SLN) registration for use of copper sulfate in wetland taro patches. Questions were raised on the deleterious effects of copper sulfate on aquatic systems. The use was not renewed when the required data (accumulation in sediment, taro tissue, and aquatic organisms) were not generated during that time.

Several farms depend on domestic ducks (Mallard breeds, e.g. Black Cayuga, Pekin) for apple snail control. Though the taro literature recommends this practice, domestic ducks, with improper care, can become pest species. The presence of large numbers of domestic ducks (feral) on water bodies in Hawaii is a concern in relation to diseases and direct competition with native species.

Feral Mallards. Farms occasionally receive stray or feral waterfowl in varying degrees of "wildness." Migrant Mallards are rare in Hawaii. Feral Mallards closely resemble migrant Mallards but are descendents of farm and pet Mallards. Feral Mallards are listed as the number one threat to Koloa due to hybridization and displacement. Farmers should return stray ducks to owners or contact the State Division of Forestry and Wildlife (DOFAW) for guidance on removal.

Disease. Die-offs of waterbirds can occur at a particular site due to disease. A disease that occurs around shallow water areas is avian botulism. Outbreaks are associated with anaerobic soil conditions (drying out soils reduces or eliminates this problem). It can be transmitted rapidly from dead to healthy birds by infected maggots. Prompt removal and disposal of dead birds and fish can control the spread of the disease. Not enough is known about avian botulism to identify precisely the factors leading to an outbreak. It is a natural toxin produced by a bacterium in pond soil. The disease affects both domestic and wild waterbirds. Avian botulism is not transmissible to humans. If suspected, contact DOFAW or the National Wildlife Health Center (808) 792-9520.

Predator control. Native Hawaiian waterbirds had no mammalian predators prior to the arrival of humans. Today introduced predators include pigs, dogs, cats, mongooses, rats, bass, bullfrogs, mynas, and cattle egrets. Aukuu are native predators of eggs and young. Dogs and cats often pursue adult birds. Birds may avoid farms with dogs. Mongooses have devastated ground nesting bird populations on nearly all main islands. Kauai and Niihau lack mongooses and are the only islands where waterbirds are known to maintain viable breeding populations without predator control. Fencing out and trapping mammalian predators, and restraining pets will greatly improve bird survival and reproduction.

Table 2 Direct and indirect effects of some invasive species on taro, wildlife, and watershed function

Invasive species	Taro Farms	Native Wildlife	Watershed Function
Apple Snails	D	I	I?
Crayfish	D	D	D
Feral Mallards		D	
Mallard Breeds	D	D?	
Cattle Egrets		D	
Feral Pigs	D	D	D
Feral Horses	D	D?	D
Feral Dogs	D	D	
Feral Cats	D	D	
Mongooses	D	D	
Phytophthora leaf blight	D	I?	I?
Pythium root rot	D	I?	I?
Weeds (e.g., *Egeria*)	D	D	D

D = Direct Impact (economic or ecological); I = Indirect Impact (economic, in species structure, water or soil quality, or secondary effects of taro being replaced by invasive plants); based on interview results

Avoid control methods that may be beneficial to taro farming and detrimental to native wildlife or vice versa. Avoid using invasive species to control invasive species. Target invasive species that will result in the greatest collective benefit for taro farming, native wildlife, and watershed functions (Table 2).

Research on pest management in taro systems is ongoing. See ADAP (1994), CTAHR (1997) or contact the CES for most recent control methods.

GENERAL

For general assistance with design and management of waterbird habitat contact the Oahu National Wildlife Refuge Complex biologists at (808) 637-6330.

These practices may apply to other types of agriculture and aquaculture such as upland taro, lotus (hasu), watercress, shrimp, and crayfish farms.

There are many unanswered questions about wildlife habitat on taro farms. Current research in Hanalei Valley will address some of these issues. It is well known that protected areas alone cannot achieve conservation goals for species *diversity, and that agriculture and wildlife conservation are not mutually exclusive. Throughout the nation there is a trend towards increasing farm size, farming intensity, monocultures, mechanization, and loss of wetlands and idle lands. All have contributed to loss of wildlife diversity. Taro farming represents an anomaly in that trend with small family-owned farms where planting and harvesting are still carried out by hand. Taro farms provide shallow open water habitat where there would likely be none. Native wildlife are an integral part of the ahupua`a and fill an important aesthetic, cultural, and ecological niche.*

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COMMON AND SCIENTIFIC NAMES OF ANIMALS AND PLANTS IN TEXT

Animals

Apple Snail (*Pomacea canaliculata*)
Bass (*Micropterus* spp.)
Black-crowned Night-Heron or Aukuu (*Nycticorax nycticorax*)
Bullfrog (*Rana catesbeiana*)
Cat (*Felis catus*)
Cattle Egret (*Bubulcus ibis*)
Crayfish (*Procambarus clarkii*)
Dog (*Canis familiaris*)
Goat (*Capra hircus*)
Hawaiian Coot or Alae keokeo (*Fulica alai*)
Hawaiian Duck or Koloa maoli (*Anas wyvilliana*)
Hawaiian Goose or Nene (*Branta sandvicensis*)
Hawaiian Moorhen or Alae ula (*Gallinula chloropus sandvicensis*)
Hawaiian Stilt or Aeo (*Himantopus mexicanus knudseni*)
Horse (*Equus caballus*)
Hihiwai (*Neritina granosa*)
Mallard (*Anas platyrhynchos*)
Mallard breeds (*Anas platyrhynchos domesticus*)

Mongoose (*Herpestes auropunctatus*)
Mosquito Fish (*Gambusia affinis*)
Mountain Opae (*Atyoida bisulcata*)
Myna (*Acridotheres tristis*)
Northern Pintail or Koloa mapu (*Anas acuta*)
Northern Shoveler or Koloa moha (*Anas clypeata*)
Pacific Golden-Plover or Kolea (*Pluvialis fulva*)
Pig (*Sus scrofa*)
Rats (*Rattus* spp.)
Striped Mullet or Ama ama (*Mugil cephalus*)
Tattler or Ulili (*Heteroscelus* spp.)
Teal (*Anas* spp.)
Tilapia (Cichlidae)

Plants
Azolla fern (*Azolla filiculoides*)
Bahia grass (*Paspalum notatum*)
Bermuda grass (*Cynodon dactylon*)
California grass (*Brachiaria mutica*)
cattail (*Typha latifolia*)
hau (*Hibiscus tiliaceus*)
honohono (*Commelina diffusa*)
Job's tears (*Coix lachryma-jobi*)
kukui (*Aleurites moluccana*)
lotus or hasu (*Nelumbo nucifera*)
marsh fleabane (*Pluchea carolinensis*)
papyrus (*Cyperus papyrus*)
parrot's feather (*Myriophyllum aquaticum*)
rice (*Oryza sativa*)
sedge (*Cyperus* spp.)
smartweed (*Persicaria* spp.)
spikerush (*Eleocharis* spp.)
watercress (*Nasturtium microphyllum*)
waterweed (*Egeria densa*)
wild rice (*Echinocloa* spp.)

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APPENDICES

A. CTAHR (College of Tropical Agriculture and Human Resources) leaflet on taro production (Uchida and Kadooka); Illustration of taro cycle (CTAHR 1997)

B. Annual rainfall and migration and breeding peaks of Hawaiian waterbirds, broken down by island

C. Plants found in wetland taro systems and habitat values

D. Case examples of wildlife habitat management

Appendix A1 CTAHR leaflet on taro production

Wetland Taro Production in Hawaii

R. UCHIDA[1] and C.Y. Kadooka[2],
[1]Agricultural Diagnostic Service Center, [2]Dept. of Plant & Environmental Protection Sciences, University of Hawaii, Honolulu, HI 96822.

Taro (*Colocasia esculenta*), a member of the Araceae, is widely used throughout the world as a food source and in Hawaii, both the corm and leaf are eaten. Wetland taro production in Hawaii is similar to that of paddy culture of rice and most of the field operations, planting and harvesting, are still carried out with hand labor (Fig. 1).

Fig. 1 Taro cultivation in Hawaii.

FIELD PREPARATION

After each harvest, the fields are left to dry and fallow for 4-6 weeks (Fig. 2). Following the fallow period, banks are repaired to prepare the paddies, called *lo'i*, to hold water. Soil samples are taken to test for pH and the basic soil nutrients. The desired pH range is 6.0 - 6.8. In most of the areas where wetland taro is grown, the critical soil levels for potassium, calcium, and magnesium are 250 ppm, 1750 ppm, and 350 ppm, respectively, using neutral 1 M ammonium acetate as the extracting agent. The critical phosphorus level is 30 ppm, and is assayed using a Modified Truog extracting solution. If liming material and phosphorus are recommended, they are incorporated into the soil during the tilling and leveling process. The paddies are then flooded and left standing for 2-3 weeks before planting (Fig. 3). This allows time for the clay and silt particles to settle and seal most of the large pores in the soil, and prevents major water loss during the growing season. It also provides time for equilibration of the liming reaction to occur if necessary . The mud in the paddies is also leveled with a rake at this time.

Fig. 2 Fallowing allows organic matter to decompose.

Fig. 3 Flooded *lo'i*.

PLANTING

Trimmed shoots with a portion of the corm, called *hulis* (Fig. 4), are the propagative material used for planting. Like rice, the *hulis* are hand planted in the *lo'i*. The planting distance is usually 2 ft. x 2 ft., which results in 10,500 - 11,000 plants per acre (Fig. 5, 6, & 7). Growing practices vary among growers; some keep the *loi's* continuously flooded, while others allow some drainage before adding water. In order to prevent the soil from cracking, the paddies are never allowed to dry once the crop has been planted. Planting is done year round.

Fig. 4 Trimmed *hulis*.

Fig. 5 One week after planting.

Fig. 6 Six weeks after planting.

Fig. 7 Five months after planting.

CULTURAL PRACTICES

Weed Control. Keeping the fields constantly flooded controls weed growth. Weeds that do grow are removed by hand. There are no herbicides cleared for use in wetland taro paddies.

Fertilizer Practice. Phosphorus and potassium applications are based on soil analyses. The present recommended amount of nitrogen is 350 lb. N per acre, split into 8 monthly applications with the last application applied at 6-8 months. The taro is harvested at 12-14 months of age. Nitrogen applications after 8 months can lead to delayed starch storage and corm growth as well as increased growth of leaves and roots. The first application is usually done 2-3 weeks after planting, when two leaves have emerged from the newly planted huli. Plant tissue analyses may also be used for guiding fertilizer practices.

HARVESTING

The *lo'i* is first allowed to dry and crack, then flooded with water again before harvesting. The drying causes some of the roots to die and makes harvesting easier. Stomping around the base of the plant facilitates breaking the roots from the corm, making it easier to remove from the soil (Fig. 8). Subsequently, the plants and corms are manually pulled from the soil, and then washed in the water (Fig. 9).

Fig. 8 Harvesting taro.

Fig. 9 Harvested taro.

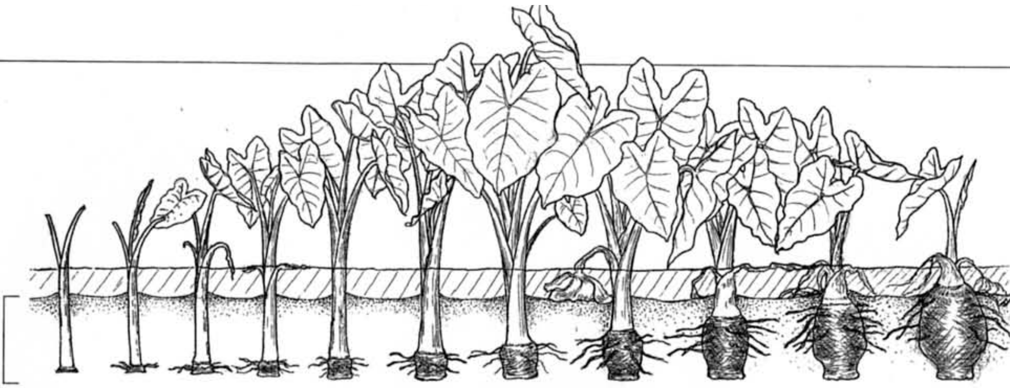
PRODUCTS

Most of the wetland taro produced in Hawaii is processed into *poi* by first boiling or steaming, and then mashing the corms into a paste, which is consumed as a starch staple. It is also boiled or baked and eaten like potato, or sliced and made into taro chips. Taro flour has also been produced, and is used to make cookies and bread. *Poi* is also used as food for infants who are allergic to baby food (Fig. 10).

Fig. 10 Products made from taro.

Appendix A2 Taro cycle (reprinted from CTAHR 1997)

General plant growth, weed control, fertilization, water requirements, and best management practices for wet taro, with an emphasis on commercial production.



Physical changes in taro plants	At least 6 inches	(illustration)				
Plant growth	Preplant	Root establishment stage (0–3 months)	Heavy leaf growth (3–5 months)	Corm growth (5–11 months)	Harvest (11–15 months)	
Lab analysis	Have soil tested		At this stage of growth (around 4 mo.) take a leaf sample and have it tested	At this stage of growth (around 6 mo.) have soil and leaf tested again		
Soil amendments	Using soil test results, incorporate treble superphosphate into soil to provide necessary P for entire crop cycle. If desired, add compost to increase organic matter. Plant in 5–10 days after applying P or about 30 days after applying compost.	N and K applications begin after at least 2 leaves have formed and should be made in several small applications (5–7), rather than all at one time, during the first two-thirds of the plant cycle. Amounts depend on tissue (leaf) and soil test results, with N and K targets generally in the range of 300–500 lb/acre/crop. As a guide, approximately 50 lb of N can be supplied by 250 lb of ammonium sulfate or 100 lb of urea. Also, 60 lb of K (K_2O) can be supplied by 100 lb of KCl. Side-dress the entire row, or band each plant individually as appropriate. Wait 7 days with no water flow so that nutrients move down into soil.		There should be no need for additional nutrients at this growth stage, because leaf growth should not be encouraged or the corm will not reach maturity in a timely manner. Try to avoid "run-on" of water containing nutrients, which may make the taro *loliloli*.		
Weed control	Remove all weeds	Carefully remove all weeds. Add azolla and adjust water levels.	Occasional weeding (avoid root and plant damage).	Weeding may be important (avoid root and plant damage).		Control weeds
Water needs	Moist soil	Around 1 inch	Water at maximum depth for planting area, generally 1–6 inches. Water flow should be stopped for at least 7 days during any fertilization or heavy weeding activity.		Moist soil, water stopped	Little, but not too dry
Best practice	Arrange for future sale of crop as appropriate	After leaf surfaces have dried, walk the edges of your planting area daily. Keep a written log of observations and results of laboratory tests and water and fertilization trials and relate them to yields and problems. Remove pests and diseased leaves and plants, and dispose of them away from the planting area.		Contact buyer. Begin to prepare next production area.	Harvest/ prepare as per buyer specifications	"Dry" fallow; cover crop optional

Appendix B Annual rainfall and migration and breeding peaks of Hawaiian waterbirds, broken down by island[1]

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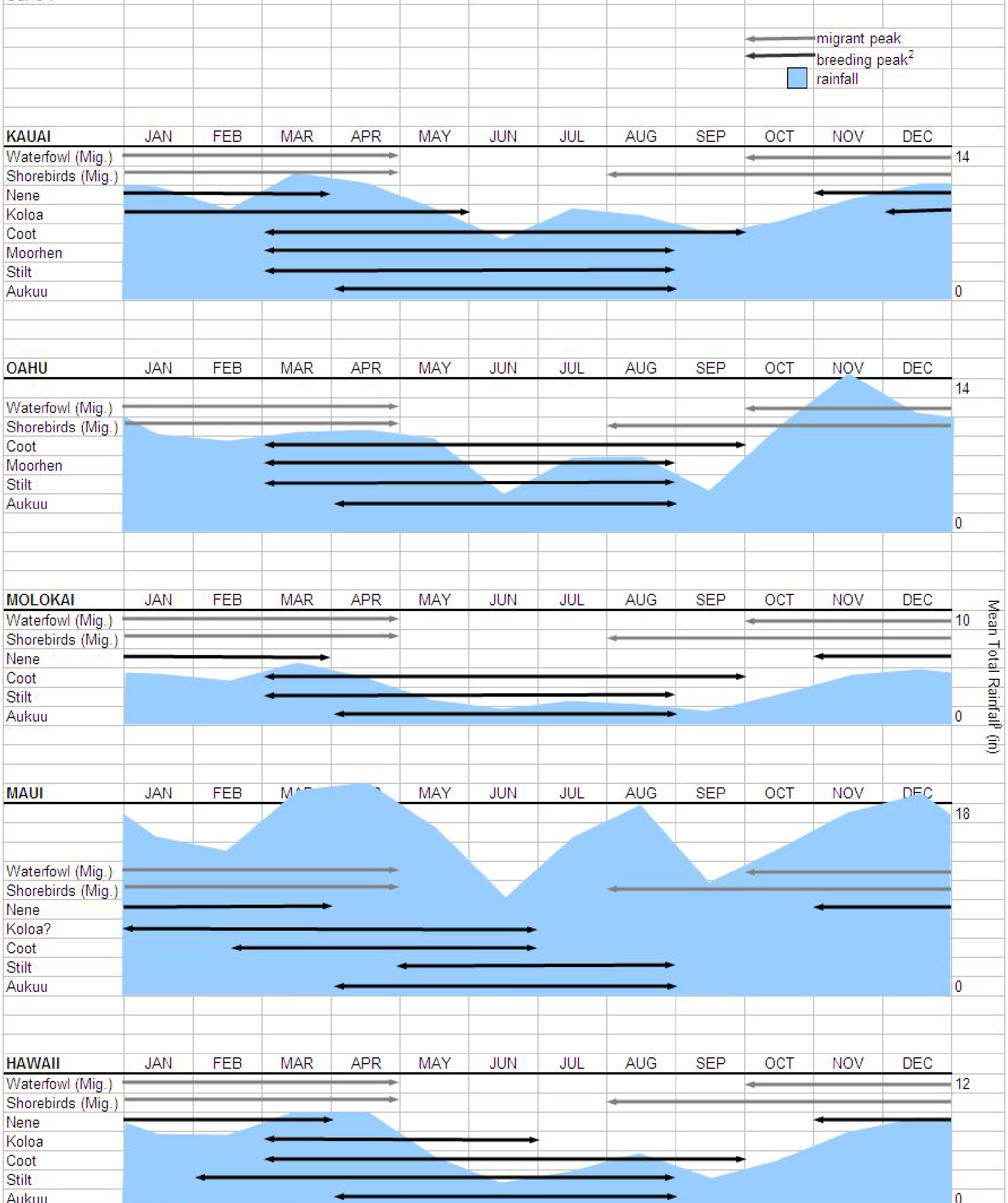

[1]Use as a broad guideline. Parameters will vary by location and year.

[2]Koloa, coot, and moorhen nest yearround depending on rainfall and other breeding conditions.

[3]Rainfall for major taro growing areas.

Appendix D Case examples of wildlife habitat management

Case Example: Waipio Valley, Hawaii
A farmer on an existing 10-ac farm agrees to fallow 1.0 ac on a 1-yr cycle for waterbird habitat. After yr 1, rotate to 1.0 ac area contiguous to first area, first area is put back into taro production, and the adjacent 1.0 acre area is fallowed for waterbirds.

Birds present: *migratory shorebirds, Koloa, coot, and Aukuu in low but consistent numbers*
Birds likely to breed in area (target species): *Koloa, coot, Aukuu*

Water management: *From January to March, the freshly tilled patch is maintained as a mudflat or flooded <2 in to provide forage for waterbirds and allow wetland plants to germinate. About March, the patch is gradually flooded to 6-12 in and maintained in that range until fall. Tilling or weed maintenance occurs in late summer if there are no signs of breeding coots and Koloa (Aukuu forage in patches and nest in trees). Then, from about September or October the patch is returned to a water depth of <2 in to provide foraging sites for incoming shorebirds. In January, the patch will be prepared for taro production.*

Case Example: Hanalei Valley, Kauai
On a new 8-ac farm, the farmer agrees to fallow 2.0 ac on a 2-3 yr cycle for waterbirds. Patches will be rotated in and out of taro production, and the agreed upon acreage remains fallow.

Birds present: *migratory waterfowl and shorebirds, Aukuu, and 2-3 pairs of Koloa, coot, moorhen, and stilt*
Birds likely to breed in area (target species): *Koloa, coot, moorhen*

Water Management*: During yr 1, water management follows the Waipio example, except in the fall of yr 1, the patch is maintained as a mudflat or flooded <2 in to stimulate the growth of annuals. In January of yr 2, the patch is slowly flooded to 6-12 in for breeding waterbirds. Water levels are stabilized in that range until about August or September when all chicks have fledged. The patch remains flooded until December for migrants. In January of yr 3, water management returns to yr 1 management. Vegetation is maintained at least 1-2 times per year to keep favorable cover at <50-75%. Dry fallows and cover crops could be incorporated into the off-peak period (September to December). In the January of yr 4, the patch will be prepared for taro production.*