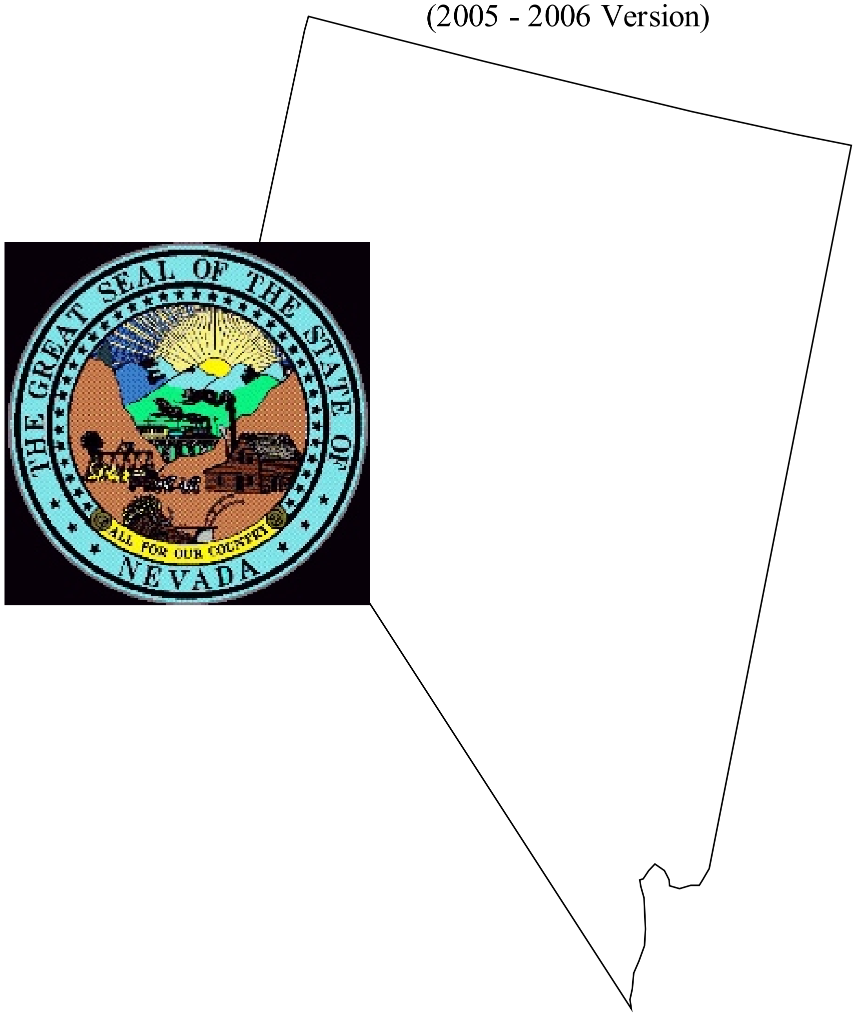
AQUATIC PEST CONTROL

Volume X

(2005 - 2006 Version)



NEVADA STATE DEPARTMENT OF AGRICULTURE

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Las Vegas, Nevada 89104-4314

Edited by Scott D. Cichowlaz

Table of Contents

Nevada Department of Agriculture
Test Taking Rules

3) All Pest Control Examinations are Monitored; and Video and Audio Taped.....

4) Anyone who cheats on an examination will be excluded from taking another pest control examination for a minimum of 6 months (NAC 555.340.7)......

5) No cell phones or pagers can be used at anytime during an examination.....

6) No unapproved study materials, notes or other aids are to be in your possession during an examination....

7) Tests must be paid for prior to examination....

8) PLEASE bring a sharp pencil, eraser and calculator...

Nevada Department of Agriculture Examination Procedure

DUE TO THE INCREASE IN NUMBER OF EXAMINES IN THE LAS VEGAS OFFICE A NEW POLICY TOOK EFFECT MARCH 1, 2005 FOR ALL NEVADA DEPARTMENT OF AGRICULTURE EXAMINATION LOCATIONS .

IF YOU **NO SHOW** FOR AN EXAMINATION OR IF YOU DO NOT CANCEL YOUR EXAMINATION APPOINTMENT WITH A **48 HOUR NOTICE**; YOU WILL HAVE TO COME IN TO THE EXAMINING OFFICE TO PRE-PAY FOR ALL YOUR EXAMINATIONS THEREAFTER.
ALL PRE-PAID EXAMINATIONS ARE NON-REFUNDABLE!

IF YOU DO MAKE AN APPOINTMENT FOR AN EXAMINATION AND/OR YOU DO **NOT** SHOW FOR THE EXAMINATION ON TIME, YOU WILL **LOSE** YOUR MONEY.

STUDY GUIDE FOR AQUATIC PEST CONTROL

Volume X

Preface and Acknowledgments

This manual was prepared as a general study manual for pest control operators to prepare you to meet the written test requirements. It does not include all the things you need to know about this subject or your pest control profession. It will, however, help you prepare for your examination. This manual deals with insect, weed and vertebrate control in aquatic areas that are used or are intended for use in and around industrial complexes, institutional complexes and dwelling units. The information contained herein is basic and practical, and is not intended to serve as a complete guide, but rather to give general information about insect, weed and vertebrate control and types of insects, weeds and vertebrates commonly found in aquatic areas of Nevada.

The information is not intended to substitute any label information or directions. All information contained herein is furnished with the understanding that no discrimination is intended and that the naming of commercial products does not imply an endorsement by the Nevada Department of Agriculture. The information and recommendations in this manual are based on data believed to be correct. However, no endorsement, guarantee or warranty of any kind, expressed or implied, is made with respect to the information contained herein.

Due to constant changing laws and regulations, the Nevada Department of Agriculture assumes no liability for the suggested use of chemicals or control techniques.

Contributors of this manual included the Nevada Department of Agriculture; US Environmental Protection Agency, Pesticide Programs; Utah Department of Agriculture and Food; Utah State University Extension Service; and Shanron M. Dobesh of the Kansas State University.

Nevada Department of Agriculture

Aquatic Plant Introduction

Plants have adapted to thrive in diverse habitats. They are most obvious in the terrestrial environment, but they also can inhabit many types of aquatic environments. Aquatic plants are more numerous in the warm, swampy areas of the southern United States, but examples can also be found in Nevada.

Aquatic plants are a natural part of the aquatic ecosystem, used by many different animals either as food or as a hiding place. Many people find aquatic plants interesting and attractive. However, as with any naturally occurring organisms, they may interfere with people's activities either by their over abundance or by their mere presence. When this occurs the plants are considered "weeds" and some control is desired.

Different problems occur in different types of waters. The main water types and their associated aquatic plant problems are as follows:

Impounded Waters (Ponds, Lakes, and Reservoirs)

The most common aquatic vegetation problems occur in impounded waters. Abundant vegetation affects the fish populations in these bodies of water. Small fish hide in the vegetation, making them unavailable to predators. This often results in overpopulation and stunting of certain species. Excessive vegetation interferes with fishing, swimming and boating, and dead, decaying vegetation produces offensive odors. A more serious problem in impounded waters are fish kills, whereby oxygen is depleted from the water by the decaying vegetation. This can occur at almost any time of year, but the most common are in mid-summer and in mid-winter during ice cover. Summer kills of fish populations usually occur after periods of hot, calm, cloudy weather. During these times the plants greatly reduce their photosynthesis, but continue to respire and often die and decompose. Winter kills of fish populations occur during periods of ice and snow cover. Ice usually allows enough light penetration for photosynthesis, but a layer of snow can block out most light. This light blockage prevents oxygen production, but respiration and decomposition continue, resulting in an oxygen shortage.

Flowing Water (Rivers, Streams, and Canals)

Aquatic vegetation is seldom a problem in the rivers and streams of Nevada. In fact, vegetation along the banks is beneficial in that it protects the banks from erosion. Problems can occur in various canals (including irrigation and flood canals), however, which are designed to transport water. Vegetation growth on banks, edges, and in very shallow water is the most common problem in Nevada. Most aquatic weed applications are done to control weeds in these areas to prevent the impedance of water flow.

Water Saturated Areas (Marshes, Seeps, and Drainage Ditches)

Aquatic plants usually are not a major problem in these areas. Encroaching vegetation may impede flow in drainage ditches. Marshes and seep areas usually cannot be used for conventional Nevada agriculture and most if not all have been identified for wildlife habitat. Weed problems can occur in cultivated fields, and right-of-ways that border these wet areas, especially in abnormally wet years. During these times the aquatic plants will invade the fields and encroach on the rights-of-ways and cause special weed control problems.

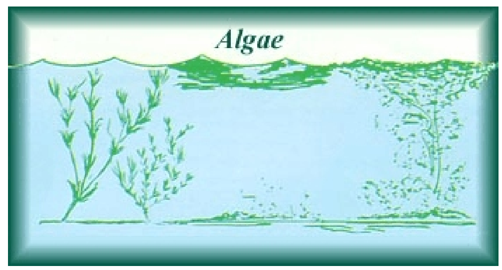
Classification of Aquatic Plants

Problem weed species must be identified before an appropriate weed control practice can be selected. Aquatic plants are classified by a similar growth habit as: (1) algae, (2) floating plants, (3) submersed plants, (4) emersed plants, and (5) marginal plants.

Algae

Three major forms of fresh water algae are: (1) phytoplankton (planktonic & microscopic), (2) filamentous, and (3) chara. Planktonic algae are usually beneficial unless water is used for human consumption. Planktonic and filamentous algae may clog filters in water treatment plants or produce undesirable tastes and odors in drinking water.

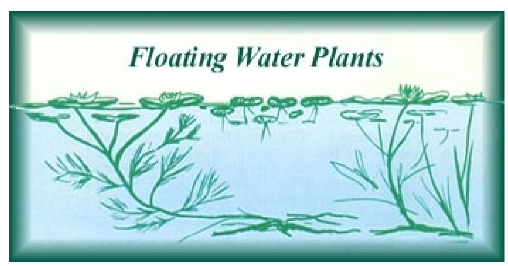
Filamentous algae interfere with irrigation systems by clinging to structures and concrete linings and clogging weirs and screens. Common filamentous algae are *Spirogyra* spp.-slimy and green; *Cladaphora* spp.-cotton mat type; and *Pithophora* spp.-horsehair clump type.



Nitella spp. and *Chara* spp. (also called muskgrass) are large green algae that are anchored to the bottom but do not extend above the surface. Stem like, with thin, leaf like structures, they are often confused with seed plants. When crushed, chara produces a musky odor.

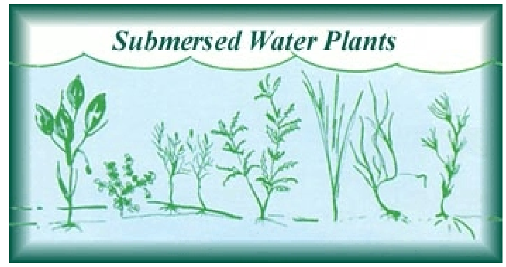
Floating Plants

Some plants are free-floating while others, rooted in the bottom, have floating leaves that rise or fall with the water level. Many floating plants grow rapidly and are among the most troublesome aquatic plants. Duckweeds (*Lemna* spp.) and watermeal (*Wolffia* spp.) are true floating plants of this group whose roots feed from water rather than soil. Rooted plants with floating leaves include waterlilies (*Nymphaea* spp.) and American lotus (*Nelumbo* spp.). Many lotus leaves float, but some extend above the surface.



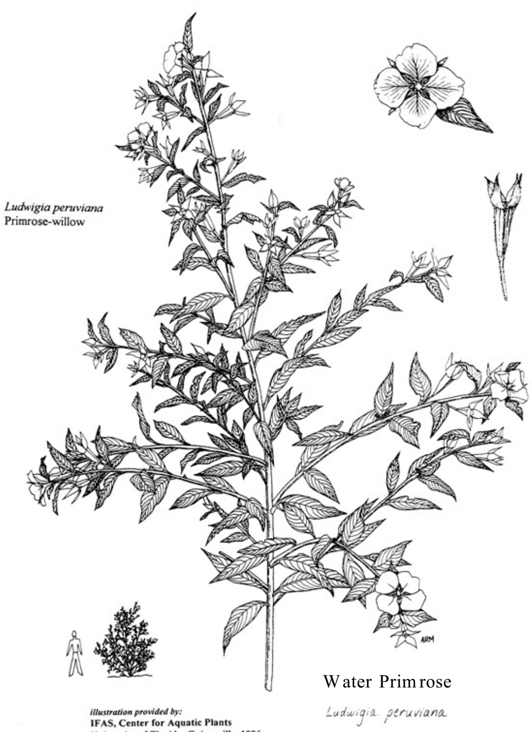
Submersed Plants

Submersed plants are true seed plants with roots, stems, and leaves. Rooted on the bottom, these plants grow chiefly below the surface although their flowers and seeds and a few leaves may extend above it. A depth of 10 to 12 feet in clear water is the limit habitat for most submersed plants. Important submersed plants include: pondweeds (*Potamogeton* spp.), elodea (*Elodea* spp.), watermilfoil (*Myriophyllum* spp.), coontail (*Ceratophyllum* spp.), naiads (*Najas* spp.), and bladderwort (*Utricularia* spp.).

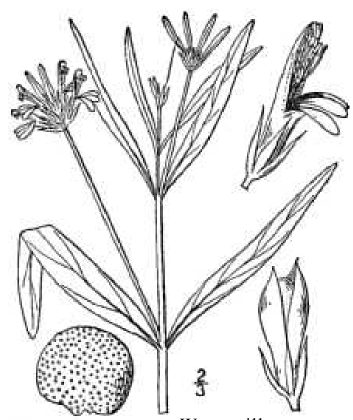


Emersed Plants

Emersed plants are rooted in the bottom and produce most of their leaves and flowers at or above the surface. Leaf shape, size and point of attachment are variable within this group. Leaves of emersed plants do not rise and fall with the water level as do those of attached floating plants. Important emersed plants include: watershield (*Brasenia* spp.), arrowhead (*Sagittaria* spp.), water primrose (*Ludwigia* spp.), and waterwillow (*Justicia* spp.).



Water Primrose



Waterwillow

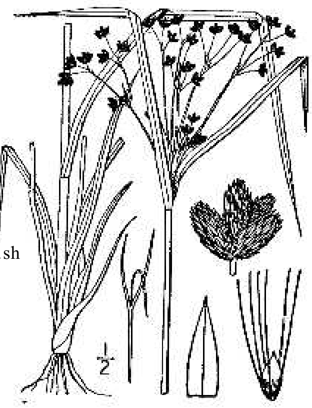
Watershield

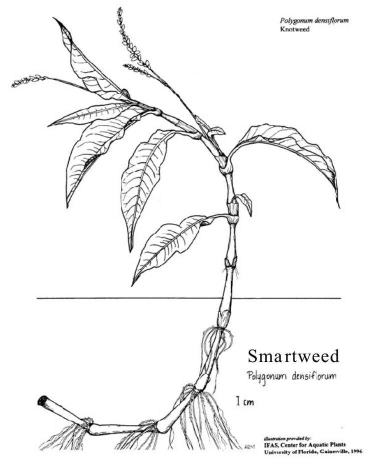
Arrowhead

Marginal Plants or Emergant Plants

Marginal plants are emersed plants that grow on saturated soil beyond the water's edge or in very shallow water. These plants vary in size, shape and habitat. They may be found growing in moist soils along shorelines into water up to 2 feet in depth. Important marginal weeds are: reeds (*Phragmites* spp.), sedge (*Carex* spp.), bulrush (*Scirpus* spp.), rush (*Juncus* spp.), cattails (*Typha* spp.), giant cutgrass (*Zizaniopsis* spp.), smartweeds (*Polygonum* spp.), purple loosestrife (*Lythrum* spp.), willow (*Salix* spp.), and Cottonwood *(Populus* spp.).

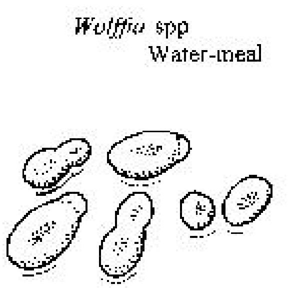

Cattails

Bulrush




Identification

Target weeds in the water use area must be correctly identified so that appropriate control practices can be selected and applied. For identification of unfamiliar aquatic plants, take samples of entire plants (roots, stems, leaves and flowers if available) to your local county Cooperative Extension agent. The county agent can help you identify the aquatic plant(s) or send the aquatic plant(s) to the appropriate identifier at the University of Nevada. This will ensure a proper identification and then proper control information can be provided if you desire management practices for these unfamiliar aquatic plants. Herbicide recommendations based on the plant identification can be provided by the county Cooperative Extension agent or a Extension Weed Specialist or your local the Nevada Department of Agriculture.



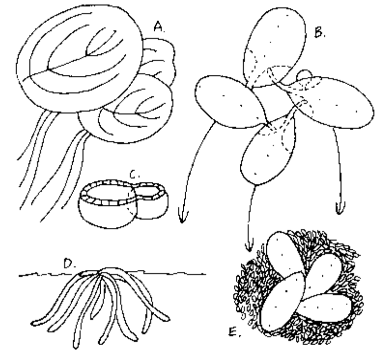
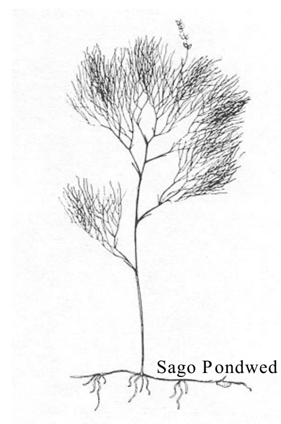
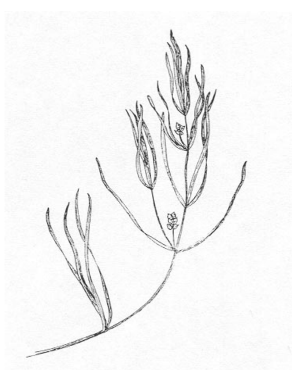
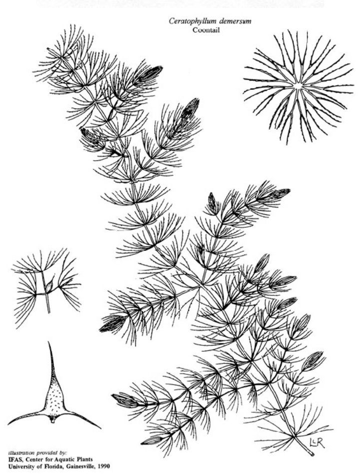


Figure 1. Duckweed, the smallest flowering plants.
Genera: A. Spirodela B. Lemna C. Wolffia
D. Wolfiella E. Lemna with Wolffia

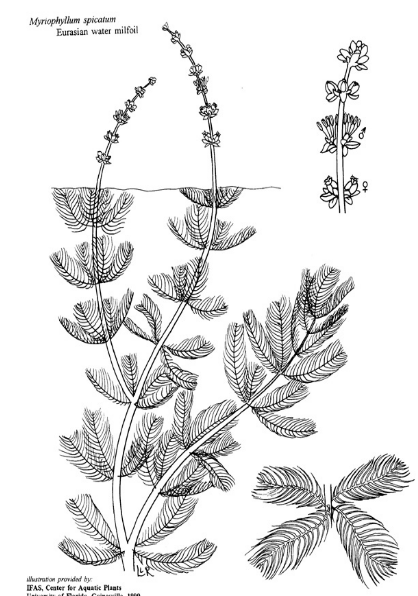




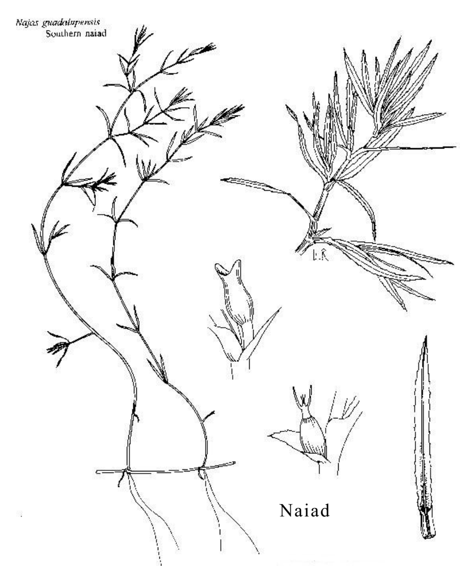
Leafy Pondweed



Coontail



Watermilfoil



Naiad

Aquatic Plant Control

Control of aquatic weeds can be subdivided into four general categories: (1) prevention, (2) mechanical, (3) biological, and (4) herbicides. Often a combination of these practices is necessary for adequate control.

Prevention

Effective planning and aquatic system management often eliminates or greatly reduces the need for costly and time consuming weed control practices. Aquatic weed problems typically occur in clear, shallow water high in nutrients. Ponds or lakes should be constructed so that shallow water areas are minimized by shaping the sides with a 3 to 1 slope (3 feet horizontal to 1 foot vertical drop) down to a depth of at least 3 feet. Existing ponds or lakes that have extensive shallow water areas can be dredged deeper, but a less expensive practice is to use a bulldozer to deepen shallow areas after the water level has receded below these areas.

Excessive nutrients should be prevented from getting into the water since they will stimulate rapid plant growth. Common sources of nutrients are runoff from livestock holding areas, septic tank drainage, heavily fertilized fields, and erosion. Stabilize banks with vegetation to prevent erosion.

Fertilizers added to water have been used to control aquatic weeds. Fertilizers stimulate the growth of planktonic algae which in turn decreases the water clarity, and thus prevents growth of submersed vegetation. Although it appears to be a good practice it usually creates other problems. Additional nutrients may cause an increase of marginal vegetation and also filamentous algae. Increased infestation of algae and other vegetation may cause oxygen depletion as the plants die and decay. Fertilization is not recommended in Nevada since most waters in Nevada's lakes and ponds contain sufficient nutrients.

Mechanical and Physical

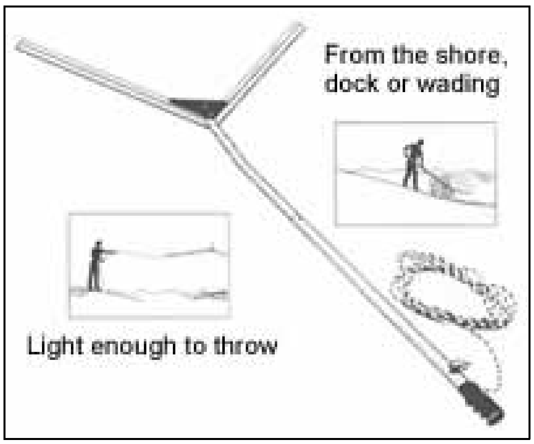
Mechanical and physical control methods will be more effective in smaller bodies of water than in larger bodies of water. Pulling marginal plants by hand is an effective reduction practice to control cattails, willows, and cottonwood trees in small ponds. Small amounts of submersed plants can be pulled out or raked by hand. Larger amounts can be removed by pulling a long chain or cable across a pond between two tractors.

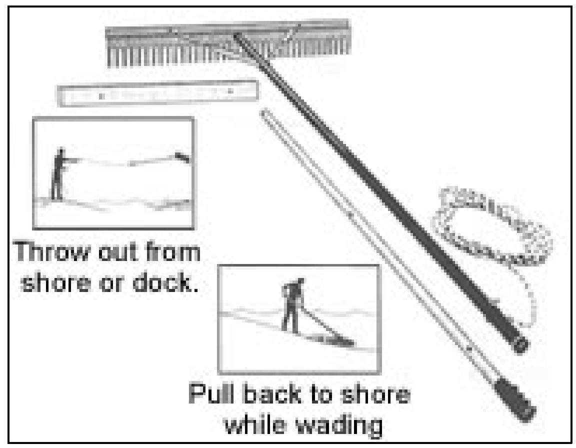
A device that is effective on submersed vegetation is a hand pulled cutter, consisting of a "V" shaped flat metal piece sharpened on the outer edge. A rod is fastened to the point and a rope attached to this. The device is thrown out into the vegetation and pulled in with a jerking motion. This cuts off the vegetation so it can float to shore where it can be raked out.

Submersed vegetation can also be controlled by shading it with fine meshed dark plastic screen similar to the type used to shade greenhouses. A large section of this material is placed over the vegetation and weighted down with rocks. This compresses and shades the vegetation so it dies. After about two weeks the screen can be moved to another area. The advantage of this method is that fishing, swimming, and boating can take place over the screen.

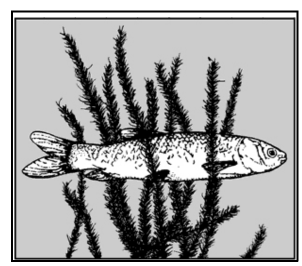
Various types of weed harvesters have been used, including a cutting device on a floating barge. As the weeds are cut, they are brought up on a conveyor and deposited on the barge. Devices such as these are expensive and disposal of the wet, heavy plant material is a problem.

All mechanical and physical control methods are labor intensive and give only short term relief. They work best on small bodies of water that can be observed closely so control can take place before the problem gets too large. These methods are especially effective in home sewage lagoons. For more effective control, use mechanical and physical control practices in conjunction with biological or chemical control methods.





Biological



Herbivorous fish, the grass carp, sometimes called the white amur (*Ctenopharyngodon idella*), is the most effective biological method to control aquatic vegetation. A member of the minnow family, this fish is native to the large rivers of China and Siberia. It will not reproduce in ponds and lakes since it needs large, fast flowing rivers for reproduction. The young grass carp feed on small crustaceans and insects, but as they grow larger, they shift their diet almost completely to plant material. They prefer some plants over others, but will consume most species of floating and submerged plants found in Nevada. They will pull out and eat some of the emersed plants, but will not be able to control them. They have voracious appetites and grow rapidly until the plants are controlled and then their growth levels off. The amount of grass carp needed for control of submersed vegetation depends on the infestation of aquatic plants. Grass carp at the rate of 20 fish per acre are needed if at least half of the area is normally covered by vegetation. For vegetation in only a narrow belt around the edge, 5 to 10 fish per acre are sufficient. Control is achieved within one year at these stocking levels. At half these levels, control may take up to two years.

Nevada has a state restriction regarding the use of grass carp! Only “Certifiied Triploid Grass Carp” (*Ctenopharyngodon idellus*) are allowed to be used in Nevada to control aquatic vegetation. A permit from the Nevada Department of Wildlife is required before the use of these fish commence. The permit can be downloaded from the Nevada Department of Wildlife website at (http://www.nevadadivisionofwildlife.org). Grass carp are readily available from most commercial fish growers at the current cost of about $4 to $8 per fish.

Stocking new, clear ponds and lakes at 3 to 5 grass carp per acre can prevent development of aquatic weed problems. Grass carp need to be at least 10-12 inches long to avoid predation if predatory fish such as bass are in the pond or lake. The initial stocking should be effective for at least several years since these are long lived fish. A few replacement fish can be stocked if aquatic weed infestation increases.

Only a few problems are associated with grass carp. They do not reproduce in standing water nor do they seem to compete or interfere with the game fish. They may, however, cause some loss of clarity of the water. Clear weedy ponds when stocked with grass carp become less clear. As the grass carp eat the vegetation, the nutrients are excreted through wastes. These in turn stimulate the production of planktonic algae which decrease the clarity.

Grass carp are highly mobile and they will readily leave a pond or lake during periods of heavy flow over the spillway. Use of mesh fence across the spillway can prevent loss of these fish.

Balance is important with grass carp
Too many = not enough food
Too few = not good weed control

Table 1. Feeding preferences of grass carp on some common aquatic plants

LOW	MODERATE	HIGH
Alligator weed Cattail Eel grass Maidencane Milfoil Parrot feather Reeds Sedges Spatterdock Torpedo grass Water hyacinth Waterlily Watermeal Watershield Yellow cowlily	Bladderwort Coontail Duckweeds Fanwort Filamentous algae Pondweeds Water pennywort Water primrose	American elodea Hydrilla Musk-grass Naiads

Waterfowl have also been used to control aquatic plants. Ducks, geese and swans will eat aquatic vegetation. Many pond and lake owners enjoy waterfowl. However, the large number of waterfowl needed for control of submersed and marginal plants results in a large amount of wastes, which fertilize the water. This often results in algae problems.

Herbicides

Herbicides may be used to control aquatic weeds but control may vary due to such factors as susceptibility of the aquatic weed(s) to the herbicide, stage of growth, rate of application; and the time of application. Some herbicides may also cause injury to fish if not applied properly. This publication provides information on alternative herbicides and their use for aquatic weed control.

Herbicides are frequently the preferred method for control of aquatic weeds in situations requiring fast results and control for several months. However, even chemical methods frequently must be combined with hand or mechanical weeding to remove remaining weeds and to prevent future spread by seed or other plant parts.

Additional information on proper use of registered herbicides for most effective aquatic pest control and least or no effect on non-target organisms or the environment can be obtained from:

- local county Cooperative Extension offices,
- Nevada Department of Wildlife,
- Nevada Department of Agriculture, and
- information from product labels and manufacturers of herbicides registered by the Environmental Protection Agency (EPA) for use in aquatic areas.

Herbicides and Their Use for Aquatic Plants

Improper Use

Improper application rates: Proper use of herbicides requires accurate application so that water, vegetation, or soil in an aquatic area is covered uniformly at the rate recommended on the product label. Properly functioning, accurately calibrated equipment is essential. Application of a herbicide below the rate recommended on the label can result in unsatisfactory control of target aquatic weeds. Herbicide application at a rate higher than the recommended rate for the product can result in greater residue and/or toxicity, **and is illegal**. Herbicides applied at rates exceeding the recommended rate can also create a hazard by contaminating water used for drinking, fish, livestock, other non-target organisms, irrigation, or other purposes.

Incorrect formulation: The use of an incorrect formulation can result in:
1. Use of a product that is not effective or safe.
2. Increased toxicity resulting in death or injury to fish and other non-target organisms.
3. Increased hazard to humans during application.
4. Increased hazard of injury to desirable non-target plants.

Faulty application: Faulty application can be the result of:
1. Improperly calibrated equipment.
2. Use of improper herbicide.
3. Use of improper rate of recommended formulation.
4. Application at improper stage of plant growth of target weeds.
5. Application of foliar applied herbicides when weeds are not growing rapidly due to unfavorable growing conditions.
6. Application to plants, water, or areas not registered for treatment on product label.
7. Application during windy or other undesirable weather conditions.
8. Improper determination of volume of lake or pond to be treated.

Hazards that can result from faulty application are listed above under Improper Application Rates and Incorrect Formulations.

Proper Use of Herbicides

All chemicals used for aquatic pest control should be applied in accordance with the directions on the manufacturer's label, as registered under the Federal Insecticide, Fungicide and Rodenticide Act.

Most herbicides have a low acute oral toxicity, but a few aquatic herbicides are poisonous to human beings, livestock, and other non-target organisms. Some herbicides are toxic to fish but most do not injure fish at concentrations required for weed control.

Proper use of herbicides will result in the most effective control of aquatic weeds and little or no effect on non-target organisms or the environment. Follow these rules:

1. Select the appropriate herbicide to control the identified target weeds.
2. Consult with Nevada Department of Wildlife or the U.S. Fish and Wildlife Service for advice if a proposed herbicide application might endanger wildlife, fish, or their habitat.
3. Apply the herbicide in accordance with all directions, warnings, and precautions on the label.
4. Store excess pesticides under lock and key out of reach of children and animals and away from food and feed.
5. Properly dispose of empty pesticide containers.

Do not apply herbicides to over ⅓ of a pond at one time. The dying / dead vegetation removes oxygen from the water and fish can't breathe, resulting in dead fish. This is usually mentioned on the herbicide label.

Table 2. Aquatic herbicides labeled for control of common aquatic plants*

KEY:
x = use
p = partial control, as indicated by manufacturer
- = no control or unknown

Aquatic Plant		Herbicide/Algaecide							
Common Name	**Scientific Name**	**AquaKleen, Navigate**	**Aquathol**	**Copper Sulfate**	**AlgaePro, Cutrine**	**Diquat, Reward**	**Hydrothol191**	**Rodeo**	**Sonar**
EMERGENT PLANTS									
Arrowhead	***Sagittaria* spp.**	-	-	-	-	-	-	x	-
Bulrush	***Scirpus* spp.**	x	-	-	-	x	-	x	-
Cattails	***Typha* spp**	-	-	-	-	x	-	x	p
Pickerelweed	***Pontederia cordata***	-	-	-	-	x	-	x	-
Purple loosestrife	***Lythrum salicaria***	-	-	-	-	-	-	x	-
Smartweeds	***Polygonum* spp**	-	-	-	-	-	-	x	-
Spike-rush	***Eleocharis* spp.**	-	-	-	-	x	-	x	p
Willow	***Salix* spp.**	-	-	-	-	-	-	x	-

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FREE-FLOATING PLANTS									
Algae - filamentous	various	-	-	x	x	some species	x	-	-
Algae - planktonic	various	-	-	-	x	-	-	-	-
Duckweed	*Lemna minor*	-	-	-	-	x	-	-	x
Water-meal	*Wolffia columbiana*	-	-	-	-	-	-	-	p
SUBMERGED ROOTED PLANTS WITH FLOATING LEAVES									
American lotus	*Nelumbo lutea*	-	-	-	-	-	-	x	-
Pondweeds									
American pondweed	*Potamogeton nodosus*	-	x	-	-	x	x	-	x
Curlyleaf pondweed	*Potamogeton crispus*	-	x	-	-	x	x	-	x
Floating pondweed	*Potamogeton natans*	-	x	-	-	x	x	-	x
Large-leaved pondweed	*Potamogeton amplifolius*	-	x	-	-	x	x	-	x
Leafy pondweed	*Potamogeton foliosus*	-	-	-	-	x	x	-	x
Sago pondweed	*Potamogeton pectinatus*	-	x	-	-	x	x	-	x
Small pondweed	*Potamogeton pusillus*	-	x	-	-	x	x	-	x
Water-lilly									
White water-lilly	*Nymphea tuberosa*	p	-	-	-	-	-	-	x
Yellow water-lilly, Spatterdock	*Nuphar* spp.	p	-	-	-	-	-	x	x
Water-shield	Brasenia schreberi	p	-	-	-	-	-	x	x

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SUBMERGED PLANTS									
Eel-grass, tape-grass	***Vallisneria americana***	-	-	-	-	-	x	-	-
Watermilfoil	***Myriophyllum* spp.**	x	x	-	-	x	x	-	x
Elodea, waterweed	***Elodea canadensis***	-	-	-	-	x	x	-	x
Horned pondweed	***Zannichellia palustris***	-	-	-	-	-	x	-	-
Hydrilla	***Hydrilla verticillata***	-	x	-	-	x	-	-	x
Naiad	***Najas* spp.**	-	x	-	-	x	x	-	x
Nitella	***Nitella* spp.**	-	-	-	x	-	-	-	-

* = The herbicides listed are commonly used in aquatic weed control activities. However, other herbicides may be commercially available for aquatic weed control activities. The information contained in this table is furnished with the understanding that no discrimination is intended and that the naming of commercial products does not imply an endorsement by the Nevada Department of Agriculture. The information and recommendations in this table are based on data believed to be correct at the time of printing.

Herbicides for Aquatic Use

Copper Algaecides

- **Copper Sulfate**
  - **Products and manufacturers:** Copper Sulfate--Chem One Corp and Griffin.
  - **Copper Sulfate use information:** Do not exceed 4 ppm in potable water. Copper sulfate controls microscopic algae, single filament algae and *Chara* (stonewort), but is not effective against submersed or emersed leafy waterweeds. Copper sulfate may be used in recommended concentrations without harm in waters for livestock and irrigation. Copper sulfate corrodes galvanized cans and most spraying equipment. Plastic sprinkling cans are convenient for applying copper sulfate.
  - **Rate of application:** Rates for algae control range from 0.67 to 5.32 pounds of copper sulfate per acre-foot of water. Four pounds of powder or crystals per acre-foot is generally strong enough to kill algae and stonewort in most waters. This concentration kills snails but does not kill fish. In alkaline water, stronger concentrations may be necessary. Treatment is ineffective in waters with total alkalinity over 250 ppm. In moderate to high alkalinity waters (over 200 ppm), the copper chelated products are recommended. Use only 1.2 pounds of copper sulfate per acre-foot in very soft water as fish may be killed at the 4-pound rate.
  - **How to apply:** Copper sulfate is available in different crystal and granular grades depending on application needs. Crystals may be scattered by hand on the surface of small ponds or placed in a burlap bag and towed behind a boat. Crystals or powder can be dissolved in water and applied by spraying the water surface. If a heavy growth of algae is present treat only one-third or one-half of the pond at a time at weekly intervals. This prevents depleting the oxygen when the mass of dead organic matter decomposes. You may treat an isolated mass of stonewort or algae without treating the whole pond.
  - **Caution:** Residual copper is toxic to many aquatic animals. Frequent and continued use may result in the kill of a large part of the fish food supply.

- **Copper Chelates**
  - **Products and manufacturer:** Cutrine-Plus and Stocktrine II-Applied Biochemists, Inc. (basic producer), K-Tea and Komeen-Griffin, and others.
  - **Herbicide use Information:** For use in lakes, private farm, fish and fire ponds; fish hatcheries; potable water reservoirs, irrigation systems, and stock tanks (Stocktrine). Apply to control algae including *Chara*, *Spirogyra,* and *Cladophora*. Chelates prevent precipitation of copper with carbonates or bicarbonates in the water. To avoid suffocation of fish due to lack of oxygen caused by decay of heavy infestations treat only 0.3 to 0.5 of the lake or pond at a time. Water treated with this product may be used for drinking, livestock watering, swimming or fishing immediately after treatment. Water treated with this product also may be used to irrigate turf, ornamental plants or crops immediately after treatment.

Copper chelates may be toxic to trout and other species of fish in soft water (<50 ppm carbonate hardness).

2,4-D

- **2,4-D Low Volatile Ester Granules**
  - **Products and manufacturers:**- Aqua-Kleen-Rhone Poulenc; Navigate-Applied Biochemists, Inc.
  - **Herbicide use Information:** For use to control specified water weeds (refer to product labels) in ponds and lakes. Granules sink to bottom and release weed killing chemical in the critical root zone area. Apply 100 to 200 pounds per acre by portable spreader or mechanical spreader. During growth season, weeds decompose in a 2 to 3 week period following treatment. Apply in spring and early summer during the time weeds start to grow. Do not apply to more than ⅓ to ½ of a lake or pond in any one month because of excess decaying vegetation which may deplete oxygen content of water, killing fish. Do not apply to waters used for irrigation, agricultural sprays, watering dairy animals, or domestic water supplies.

- **2,4-D Amine**
  - **Product and Manufacturer:** Several
  - **Herbicide use information:** For use to control aquatic weeds and weeds adjacent to water. Apply for control of annual weeds, perennial weeds, and woody plants. Do not apply to more than ⅓ to ½ of a lake or pond in any one month because of excess decaying vegetation which may deplete oxygen content of water, killing fish. Do not apply to waters used for irrigation, agricultural sprays, watering dairy animals, or domestic water supplies.

- **Diquat**
  - **Products and manufacturers:** Reward and Diquat- Zeneca and Weedtrine D-Applied Biochemists.
  - **Herbicide use information:** May be fatal if swallowed, inhaled or absorbed through skin. Skin contact will cause severe skin irritation. Do not get material on skin, eyes or clothing. Contact with skin may increase danger of absorption. For application only to ponds, lakes, and drainage ditches where there is little or no outflow of water and which are totally under control of product's user. Diquat is rapidly absorbed by aquatic plants and begins to work immediately upon contact. Plant tissue is destroyed, causing wilting and loss of foliage. Do not use treated water for animal consumption, spraying or irrigation for 14 days after treatment. Do not apply within ¼ mile of any functioning potable water intake. Treatment of dense weed areas can result in oxygen loss from decomposition of dead weeds. Treat only ⅓ to ½ of the dense weed area at a time to avoid fish suffocation from oxygen loss and wait 10-14 days between treatments. *Do not apply to muddy water.* Apply Diquat in early season to control submersed weeds before weed growth has reached surface. Diquat will control the following submersed weeds infesting still ponds, lakes and ditches: bladderwort, coontail, elodea, naiad,

pondweeds, and watermilfoil. Other aquatic weeds controlled include duckweed, cattails and some filamentous algae.

- **Endothall**
  - **Products and manufacturers:** Aquathol and Hydrothol 191-Elf Atochem.
  - **Herbicide use information:** Aquathol and Hydrothol 191 are different formulations of endothall and are both available as granular or liquid formulations. Hydrothol controls most algae and submersed plants, but is toxic to fish at dosages in excess of 0.3 ppm. Aquathol controls most submersed plants and is not toxic to fish, but does not control algae. Apply in late spring or early summer when weeds are actively growing. Do not use treated water for irrigation, agricultural sprays, livestock, or domestic purposes for at least 7 to 25 days after treatment.

- **Fluridone**
  - **Product and manufacturers:** Sonar AS and Sonar SRP- SEPRO.
  - **Sonar use information:** For management of aquatic weeds in fresh water ponds, lakes, reservoirs, drainage canals and irrigation canals. Sonar is absorbed from water through leaves and shoots, and from hydrosoil by the roots. Sonar causes chlorosis at terminal bud or growing points of plant, then plants slowly deteriorate. Complete weed removal may require 30 to 90 days. Sonar AS is effective in controlling duckweed; certain emersed weeds including spatterdock and waterlily; certain submersed weeds including bladderwort, coontail, elodea, naiads, pondweeds, and watermilfoil; and certain shoreline grasses. Sonar provides partial control of certain vascular aquatic weeds including American lotus, arrowhead, cattail, rush, and smartweed. For best results, apply Sonar before initiation of weed growth or when weeds begin actively growing.

NOTE: Users must consult their State Fish and Game Agency or the U.S. Fish and Wildlife Service before making applications. Do not apply in lakes, ponds, or other bodies of water where crayfish farming is performed. There are no label restrictions against swimming or fishing in water treated with Sonar. There are no restrictions on consumption of treated water by humans, pets, and livestock.

- **Fosamine**
  - **Product and manufacturer:** Krenite--Du Pont.
  - **Krenite use information:** For control of susceptible perennial weeds and brush species on non-cropland adjacent to and surrounding domestic water reservoirs, streams, lakes and ponds, as well as drainage ditch banks. Krenite, a water soluble liquid, is nonflammable and nonvolatile. Brush controlled includes cottonwood and willow. Apply with surfactant and make a single foliar application during the period from July to first fall coloration. For control of only a portion of a plant, as in trimming, direct the spray to thoroughly cover only the section of the plant to be controlled. Do not apply Krenite directly to water.

- **Glyphosate**
  - **Product and manufacturer:** Rodeo--Monsanto.
  - **Rodeo use information:** This product may be used in and around aquatic sites, including all bodies of fresh and brackish water, which may be flowing, non-flowing or transient. This includes lakes, rivers, streams, ponds, seeps, irrigation and drainage ditches, canals, reservoirs, and similar sites. There is no restriction on use of water for irrigation, recreation, or domestic purposes. Apply Rodeo plus nonionic surfactant approved for aquatic sites as directed on the label to control or partially control marginal weeds, woody brush and trees listed on the label. Aquatic plants controlled include cattails, annual and perennial smartweeds, spatterdock, and willow. Perennial plants generally are best controlled when treated during the flowering stage of growth. Do not apply this product within 0.5 mile upstream of potable water intakes, unless intake is turned off for a minimum of 48 hours after application.

- **Imazapyr**
  - **Product and manufacturer:** Habitat–BASF
  - **Habitat use information:** Applications may only be made for the control of undesirable emergent and floating aquatic vegetation in and around standing and flowing water, including estuarine and marine sites. Applications may be made to control undesirable wetland , riparian and terrestrial vegetation growing in or around surface water when applications may result in inadvertent applications to surface water.

- **Triclopyr**
  - **Product and manufacturer:** Renovate 3–SePro
  - **Habitat use information:** For control of emersed, submersed and floating aquatic plants in aquatic sites such as ponds lakes, reservoirs, non-irrigation canals and ditches which have little or no continuous outflow marshes and wetlands, including broadleaf and woody vegetation bands and shores within or adjacent to these and other aquatic sites.

- **Aquatic dyes**
  - **Product and manufacturer:** Aquashade-Applied Biochemists.
  - **Aquatic dye use information:** These products are a mixture of blue and yellow dyes that intercept light penetration in water. Aquatic dyes do not directly control the plants through herbicidal activity, but limit growth of plants below the water surface through shading effect. Primarily for control of submersed, rooted weeds, and some algae. Should only be used in bodies of water with little or no through flow, in order to maintain dye concentration. Products should be applied before foliage reaches the water surface. These products are nontoxic to fish, wildlife, livestock, humans, and turf. Do not use where water is used for human consumption. Safe for swimming after complete dispersal. May be undesirable to some individuals due to artificial appearance of water.

Table 3. Summary of Water Use Restrictions and Waiting Periods, in days.

	HUMAN USES			ANIMAL USES		IRRIGATION USES		
Herbicide/ Algaecide	Drinking	Swimming	Fish consumption	Lactating	Meat	Turf	Forage	Food crops
AlgaePro	0	0	0	0	0	0	0	0
AquaKleen	---Do not apply to waters used for irrigation, agricultural sprays, watering dairy animals, or domestic water supplies.--							
Aquathol K	7-25	0	3	7-25	7-25	7-25	7-25	7-25
Aquathol Granular	7	0	3	7	7	7	7	7
Copper sulfate	0	0	0	0	0	0	0	0
Cutrine	0	0	0	0	0	0	0	0
Diquat	14	1	0	14	14	14	14	14
Hydrothol 191	7-25	0	3	7-25	7-25	7-25	7-25	7-25
Navigate	---Do not apply to waters used for irrigation, agricultural sprays, watering dairy animals, or domestic water supplies.--							
Reward	1-3	0	0	1	1	1-3	1-3	5
Rodeo	Note 1	0	0	0	0	0	0	0
Sonar	Note 2	0	0	0	0	30	30	30

Notes:
1. Do not apply within ½-mile of a potable water intake.
2. Do not apply within ¼-mile of a potable water intake.

How to Calculate Area and Volume of a Body of Water

Area- Some chemicals are applied at a certain rate per surface area (square feet or acres). Area can be calculated by multiplying average length times average width. This is easy if the body of water is rectangular or oval in shape. If a more accurate estimate is desired, or if the body of water is an irregular shape, the graph paper method should be used. Length and width should be measured in several places. These measurements should then be transferred on to a sheet of graph paper according to a scale. Then the shoreline can be drawn in with the proper curvatures. The area can then be determined by counting the squares and multiplying this by the scale area for each square. For example: if the scale is 1 square = 5 feet, then the area of 1 square = 5 x 5 or 25 square feet.

The area then can be expressed as square feet or acres. One acre = 43,560 square feet.

$$\text{Surface area of pond in acres} = \frac{\text{pond area in square feet}}{43{,}560\ \text{sq. ft.}}$$

Volume- Most herbicides are applied on the basis of volume as a certain number of parts per million (ppm) or as a certain amount per acre-foot (1 acre of surface water that is one foot deep). To find volume, the average depth must be determined. This is done by taking numerous evenly spaced depth measurements. The accuracy of the average depth estimate is increased as the number of depth measurements increases. Shallow measurements must also be included or the estimate will be too high. This calculated average depth is then multiplied by the surface area determined by the method described earlier. If all the measurements were made in feet, the calculated volume will be in cubic feet. This number can be used to calculate the amount of herbicide product recommended on the label. Aquatic herbicide application is often expressed on a per acre-foot basis.

$$\text{Volume of pond in acre-feet} = \frac{\text{Pond volume in cubic feet}}{43{,}560\ \text{sq. ft.}} \quad \text{OR}$$

$$= \frac{\text{Pond area in square feet} \ \text{X} \ \text{average depth in feet}}{43{,}560\ \text{sq. ft.}} \quad \text{OR}$$

$$= \text{Pond area in acres} \ \text{X} \ \text{average depth in feet}$$

Flow - If a chemical must be applied to flowing water (canal or stream) the flow rate needs to be determined. Then based on the concentration desired in the water the chemical introduction rate can be calculated. The flow rate can be calculated by picking a section of the canal or stream with straight sides and fairly even bottom for making the necessary measurements. The width is measured and then at this point a transect of evenly spaced depth measurements should be taken. The width is multiplied by the average depth to get the cross section area. The surface velocity of the flow should be measured at several places along this transect to get the average velocity. This can be done by timing an object as it flows over a measured distance of several feet or a flow meter can be used. The velocity in feet per second is multiplied by the cross section area (in square feet) to get flow in cubic feet per second (cfs). This needs to be multiplied by a bottom friction factor (a) to reduce the amount. For a smooth even bottom this factor = 0.9; for a rough or rocky bottom this factor = 0.8. It should be *noted* that due to flowing nature of treated streams, the chance of contaminating non-treatment areas is very high. A detoxification program may have to be incorporated into the treatment program. Also due to the difficulty of accurate stream flow determinations and length of time to treat, the applicator should check with the state fish and game agency and/or the state department of health and environment before treating any flowing water.

Nuisance Animal Control

Occasionally the presence or activity of a type of animal interferes with the management objective for a body of water. Such animal species are normally present in the system but become too abundant, thus posing a problem, or they may be species that invade the body of water and their activities cannot be tolerated. This section presents some of the more common problems created by nuisance aquatic animals and discusses control methods.

Invertebrates

Certain invertebrates, other than parasite and disease organisms of fishes, can become problems in ponds or lakes used for recreation or for aquaculture.

Snails may, in special cases, become the intermediate host for the parasite that causes swimmer's itch. It may be impractical to break the cycle by eliminating the final hosts (ducks or muskrats), but partial control can be achieved by reducing the snail population. This can be done chemically by copper sulfate used at the same dosage for control of algae. Nonchemical control methods include controlling aquatic vegetation and stocking with snail eating fishes such as catfish and redear sunfish.

Predaceous aquatic insects and crayfish are often a problem in aquaculture ponds which are stocked with newly hatched fish (fry). If these predators are not controlled, fish survival may be very low. Various chemicals are effective in controlling aquatic insects. Insecticides registered for mosquito control in aquatic environments may also be used to control other aquatic nuisance organisms if: (1) The pesticide is applied at concentrations or frequencies that are less than those stated on the label, (2) Use on the target pest is not expressly prohibited, (3) The application is compatible with and nontoxic to the crop, animal, or site specified, and (4) The method of application is not prohibited. Pesticides that meet these requirements include *Bti* (*Bacillus thuringiensis* Berliner var. Israelensis), methoprene (Altosid); mineral oils, naled (Dibrom); parathion and petroleum oils; and solvents. Other insecticides are also registered to control mosquitoes in aquatic situations, but these may be toxic to fish. They include dichlorovos (DDVP), fenthion (Baytex), malathion (Carbophos), methoxychlor (Methoxcide), pyrethroids, and temephos (Abate). Read the label carefully, observe all prohibited uses, and follow all directions concerning application methods.

Whatever chemical is used, care must be taken to avoid exposure to non-target organisms and the treated water must be isolated to prevent contamination of other water. Always follow label directions and precautions. The application of unapproved compounds could lead to contamination of the water and soil, kills of desirable organisms, and residues in fish flesh.

Fishes

Fish populations frequently become unproductive from either an over abundance of stunted desirable fishes or contamination by undesirable fish species. Adjustment of the fish population may bring it back into a productive situation. Other times it may be necessary to completely remove the fish population and start over. Complete removal can be accomplished by totally draining the body of water or by chemical treatment. Chemical removal of fish populations is a widely practiced management procedure applied to ponds and lakes used for recreation or for aquaculture.

Many chemicals are toxic to fish, but most of these affect non-target organisms, cause environmental contamination, or later show up as residues in fish flesh. A few chemicals have undergone the necessary testing required for registration.

Amphibians

Amphibians are generally beneficial to the aquatic environment and are desired. In certain situations salamanders or bullfrogs can become a problem in fish culture ponds. There are no pesticides registered for the control of these animals. Control is limited to physical means in compliance with Nevada Department of Wildlife regulations.

Reptiles

Aquatic turtles and snakes can be common components of the aquatic ecosystem. In general they do not cause any problem to the fish population, and if left alone no injury to humans. In certain situations some humans may find them annoying and in some aquaculture ponds they may reduce fish production. There are no pesticides registered for the control of aquatic reptiles. Control can usually be accomplished by trapping or shooting. Before any control is attempted, the current Nevada Department of Wildlife regulations should be checked and followed.

Birds

Birds usually add to the esthetics of a body of water. In rare situations, aquatic birds can become a problem. Excessive waterfowl in a recreational pond or lake can cause disturbance and/or excessive nutrient enrichment of the water with their wastes (eutrophication). In aquaculture ponds and lakes, fish-eating birds can have a significant impact on the fish mortality. In both these types of situations, the bird species involved are classes of migratory birds and are protected by federal law. Any control measure must be preceded by acquiring the proper permits. One must obtain a permit from U.S. Fish and Wildlife Service or check with the Nevada Department of Wildlife, or with the Wildlife Services Specialist, Nevada Department of Agriculture / USDA-APHIS-WS, for the control procedures.

Mammals

The aquatic mammals that cause the greatest problems are the rodents; beavers and muskrats. These rodents cause damage by burrowing into dikes, levees, and dams. This weakens the structures often causing cave-ins, leaks, and increased bank erosion. Also their damming activity can clog culverts, overflow structures, and streams.

The best control methods involve trapping (when legal). Other nonchemical methods include reducing the food supply, installing protective barriers, and shooting. Chemical control may consist of the use of repellents, fumigants, and baits. If control methods other than trapping are to be used, the U.S. Fish and Wildlife Service, the Nevada Department of Wildlife, or the Wildlife Services Specialist, Nevada Department of Agriculture / USDA-APHIS-WS, must be contacted for the details of the current restrictions.

Public Health Concerns

Pest control activities involving public health, include the control of insects or other animals that transmit diseases to man. These animals, which are capable of carrying a disease organism or parasite from one host to another, are called vectors. These pest control programs are usually directed against these vectors in the belief that controlling the vectors will control the disease. The success of this approach is evident by the eradication of malaria and yellow fever from many parts of the world through control of the mosquito vectors. Currently, West Nile Virus (WNV) vectored by mosquitoes has been of great interest and the advice has been to avoid mosquitoes, their habitat and reduce their ability to reproduce around the home or living area.

Public health considerations remain the basis for most vector control programs, but other factors may also be important. For voters approving taxes to support a vector control program, the immediate nuisance impact of mosquitoes, flies, and rodents actually may be of greater importance than the more remote public health implications. Severe nuisance problems may have economic effects by discouraging tourism. Agricultural damage may result when vectors weaken livestock or transmit disease to them.

Successful control of a vector pest involves several steps. The pest must be accurately identified, and its biology must be adequately understood. With this information, the next steps -- evaluation of the problem and choice of a control strategy -- may be undertaken. Implementation of the control measures selected is the final step. If this step is to be successful, it must be based on knowledge and understanding of the pertinent technology and safety precautions.

The communities supporting a vector control program will be more cooperative and satisfied if they understand the general methods and goals of the program. The entire control program must reflect the current legal situation. This part of vector control should not be ignored.

Mosquitoes

Mosquitoes belong to the order Diptera and the family Culicidae. They are an abundant group of flies that are a dominant pest of man and domestic animals, acting as vectors for malaria, filariasis, yellow fever, dengue fever, encephalitis (WNV, SLE & WEE), and dog heartworm. The larval stages are aquatic, and the adults differ from all other flies by having scales on their wings and usually on their body as well.

Most mosquitoes belong to five genera, *Anopheles, Aedes*, *Psorophora*, *Culiseta* and *Culex*. Mosquitoes belonging to the genus *Psorophora* are generally vicious biters and behave like the floodwater species of the genus *Aedes*.

Members of genus *Anopheles* are vectors of malaria and are known as "malaria mosquitoes." Although all species of this genus are believed to transmit malaria, only two species are known to transmit it in the United States.

The floodwater mosquito, genus *Aedes*, is an important pest mosquito, some being vicious biters. *Aedes* is the most common pest mosquito in Nevada. The mosquito *Aedes aegypti* is a potential carrier of yellow fever and dengue fever, but this species doesn't occur in Nevada.

Culex tarsalis feeds on the blood of birds, large mammals and humans and is the most important vector of Western equine (WEE), St. Louis encephalitis (SLE),and WNV. In the spring, it will feed on birds, but it feeds on mammals during the summer.

Female adult mosquitoes of most species suck blood, and a blood meal is required for egg production in these species. Adult females of a few species and males of all species feed on nectar and other plant juices.

■ Eggs

Generally the female lays her eggs on or near water. The eggs of genus *Aedes*, which are laid separately near water, only hatch when they are flooded, and they may hatch after being dry as long as two years or more. Incubation periods vary, depending on species and temperature, but generally are 16 to 24 hours.

The eggs of *Anopheles sp.* are laid separately directly on the water surface and are provided with floats on the sides of the egg.

Genus *Culex* lays its eggs stacked vertically in rafts, which float on the surface of the water.

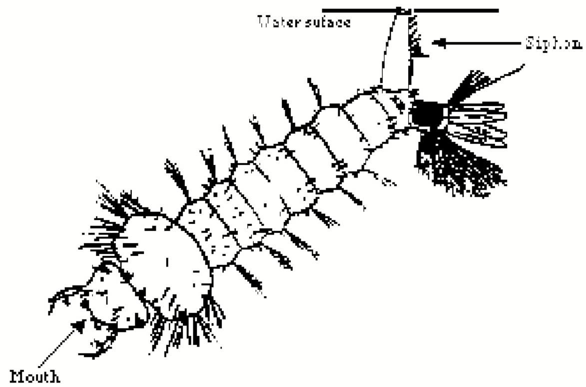
Egg Raft
Typical of all *Culex* and *Culiseta* species

■ Larvae

The larvae or "wigglers" of most species feed on algae and other organic material. Larva of a few species are predaceous and feed on other mosquito larvae. The larvae breathe at the surface of the water through a breathing tube (siphon), with the exception of genus *Anopheles,* which lacks a breathing tube (siphon) but has a pair of spiracular plates. Larvae of the genus

Anopheles may be distinguished from the larvae of other genera because they lay parallel to the surface of the water while breathing. The larvae of other genera of mosquitoes hang down at an angle from the surface of the water.

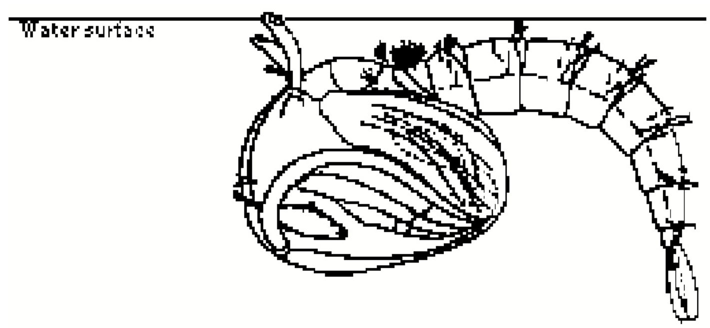
Mosquito larvae grow by a series of four molts, where the entire skin is shed. After the fourth molt, the pupa appears. The period of time between molts varies and is largely dependent on the quantity and quality of food and environmental conditions. Warmer water temperatures shorten this period of time.



Because mosquito larvae don't have to depend on aeration of the water for survival, a very large number of larvae can live in a relatively small amount of water, even if it's foul.

- **Pupae**

Mosquito pupae or "tumblers" are comma shaped and have a pair of breathing tubes or "trumpets" near the head rather than the single siphon near the tail that the larvae have. Pupae don't feed but remain quite active. Unless disturbed, this stage remains at or near the water surface. Pupae are more resistant to many insecticides than are larvae. The pupal stage lasts only from two to four days, depending on temperature. During this time, the adult mosquito is forming within the pupal skin.



When emergence time approaches, the pupa becomes less active. Within a short period of time, the pupal skin splits and the adult mosquito emerges, rests on the water surface until the skin hardens and the wings dry, and eventually flies away.

- **Adults**

Mosquitoes act as vectors of several very important human diseases: malaria, yellow fever, filariasis, dengue, encephalitis, and other diseases. The adults of two major groups, (*Anopheles* and *Culicidae*) may be identified by the angle their body makes with the surface they are resting on. The *Anopheles* rest with their proboscis and abdomen in a line at an angle to the surface. The *Culicidae* rest with their proboscis and abdomen at an angle and their abdomen parallel to the surface.

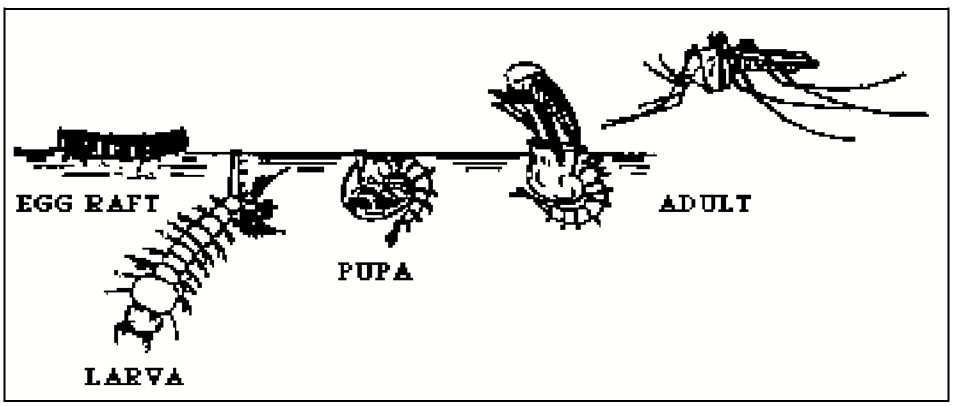
There are three primary factors that attract mosquitoes to their host. In order of importance, they are moisture, warmth, and carbon dioxide (CO_2). Amino acids and estrogens are capable of enhancing these primary factors. This is thought to be why some people seem to be more attractive to mosquitoes than others.

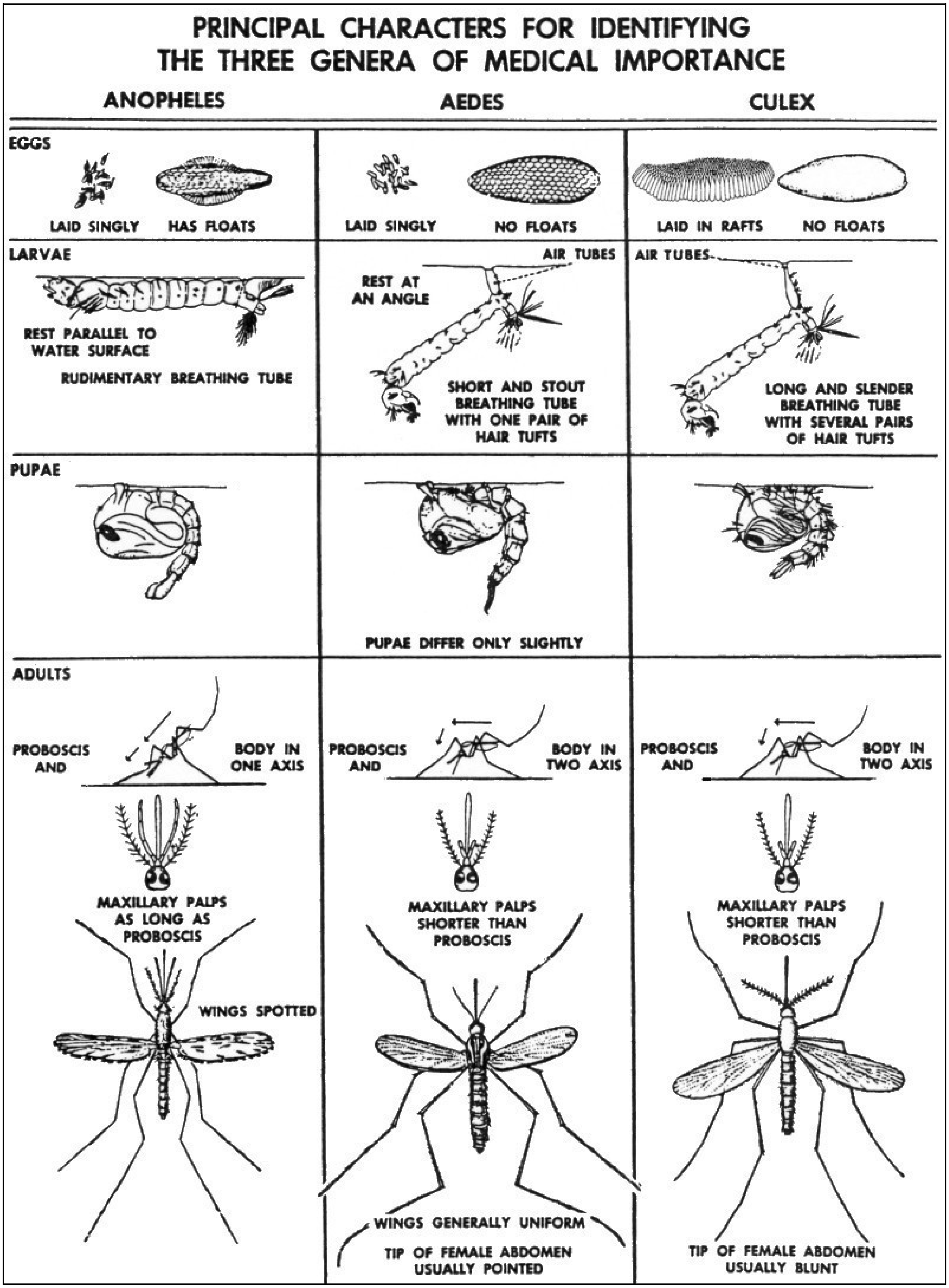
The flight range of mosquitoes interests mosquito control districts; it helps them determine the possibility of reinfestation from an area outside the district where control measures aren't taken. The flight range varies with species, time of year, wind direction, and the distance the mosquitoes must fly to find warm blooded animals on which to feed.

Studies have been done in the rice growing area of Yolo County, California, with *Culex tarsalis* marked with fluorescent material and recaptured at various distances from their point of release using CO_2 baited traps which attract only the blood seeking female. It was found that dispersion takes place in all directions if the wind speed is less than two miles per hour. (The greatest distance of recapture upwind was 2¾ miles!) If the wind speed is above four miles per hour, the dispersion is downwind with very little movement upwind. If the wind is above six miles per hour, the effective distance of dispersion doesn't increase appreciably, because such high winds discourage flight.

A similar study done in the Sacramento Valley with *Anopheles freeborni* recorded flights as far as 17.5 miles, with a small portion of the female population migrating into the foothills at a distance of ten miles.

As can be seen, these mosquitoes can fly for great distances, which makes them hard to control.



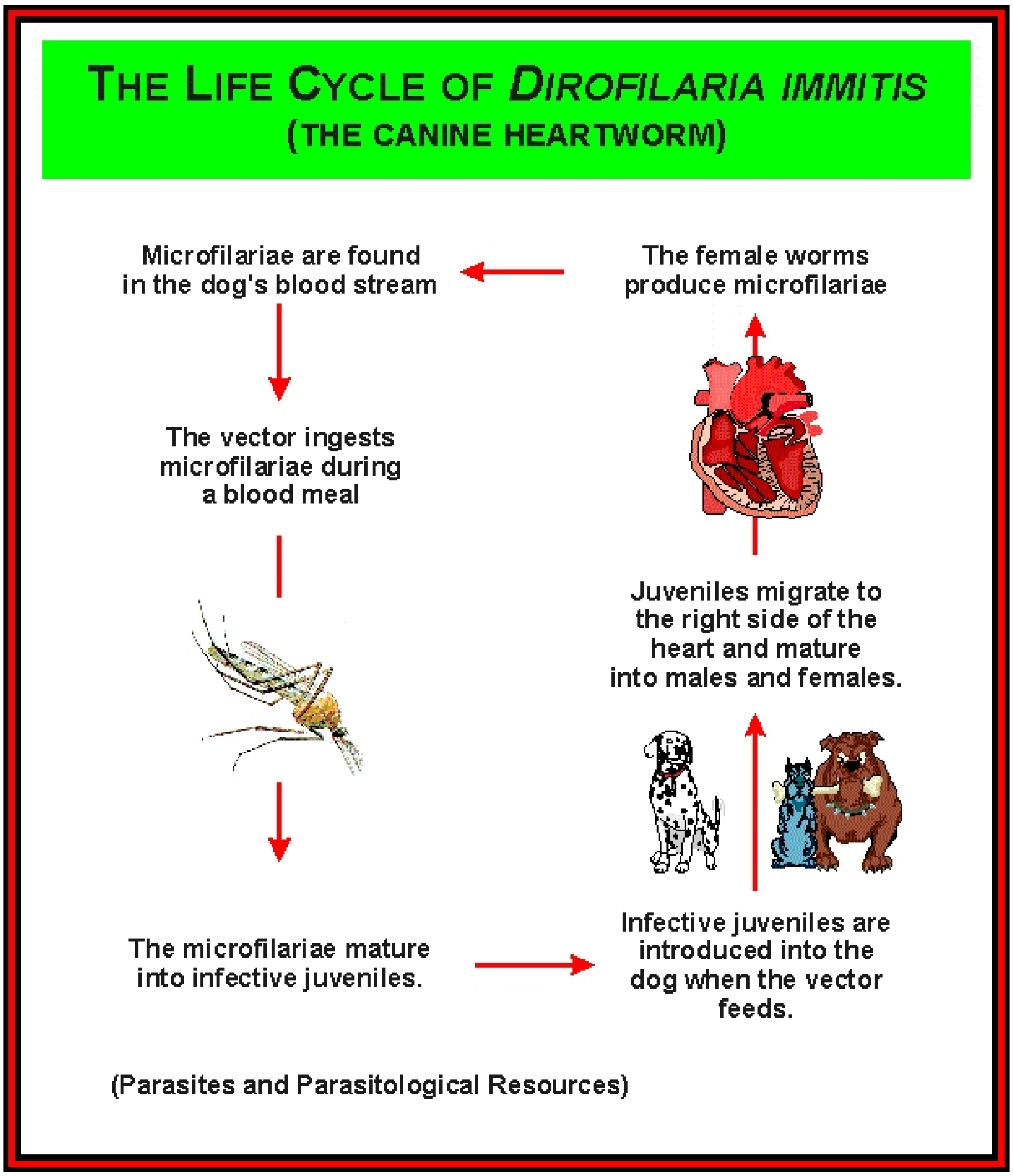

PRINCIPAL CHARACTERS FOR IDENTIFYING
THE THREE GENERA OF MEDICAL IMPORTANCE
ANOPHELES
AEDES
CULEX
EGGS
LAID SINGLY
HAS FLOATS
LAID SINGLY
NO FLOATS
LAID IN RAFTS
NO FLOATS
LARVAE
REST PARALLEL TO WATER SURFACE
RUDIMENTARY BREATHING TUBE
AIR TUBES
REST AT AN ANGLE
SHORT AND STOUT BREATHING TUBE WITH ONE PAIR OF HAIR TUFTS
AIR TUBES
LONG AND SLENDER BREATHING TUBE WITH SEVERAL PAIRS OF HAIR TUFTS
PUPAE
PUPAE DIFFER ONLY SLIGHTLY
ADULTS
PROBOSCIS AND
BODY IN ONE AXIS
PROBOSCIS AND
BODY IN TWO AXIS
PROBOSCIS AND
BODY IN TWO AXIS
MAXILLARY PALPS AS LONG AS PROBOSCIS
WINGS SPOTTED
MAXILLARY PALPS SHORTER THAN PROBOSCIS
MAXILLARY PALPS SHORTER THAN PROBOSCIS
WINGS GENERALLY UNIFORM
TIP OF FEMALE ABDOMEN USUALLY POINTED
TIP OF FEMALE ABDOMEN USUALLY BLUNT

Mosquito-borne Diseases

Mosquitoes cause more human suffering than any other organism -- over one million people die from mosquito-borne diseases every year. Not only can mosquitoes carry diseases that afflict humans, they also transmit several diseases and parasites that dogs and horses are very susceptible to. These include dog heartworm, West Nile virus (WNV) and Eastern equine encephalitis (EEE). In addition, mosquito bites can cause severe skin irritation through an allergic reaction to the mosquito's saliva - this is what causes the red bump and itching. Mosquito vectored diseases include protozoan diseases, i.e., Malaria, filarial diseases such as dog heartworm, and viruses such as dengue, encephalitis and yellow fever. CDC Travelers' Health provides information on travel to destinations where human-borne diseases might be a problem.

Malaria is an ancient disease probably originating in Africa. The malaria parasite (plasmodium) is transmitted by female *Anopheles* mosquitoes. The term malaria is derived from the Italian 'mal-aria" or "bad air" because it was thought to come on the wind from swamps and rivers. Scientists conducted much research on the disease during the 1880s and early 1900s. Approximately 40% of the world's population is susceptible to malaria, mostly in the tropical and sub-tropical areas of the world. It was by and large eradicated in the temperate area of the world during the 20th century with the advent of DDT and other organochlorine and organophosphate mosquito control insecticides. However, more than three million deaths and 300 - 500 million cases are still reported annually in the world. It is reported that malaria kills one child every 40 seconds. In the United States malaria affected colonization along the eastern shore and wasn't effectively controlled until the 1940s when the *Anopheles* mosquitoes were controlled. A resurgence occurred during the 1960s and early 1970s in the United States due to returning military personnel from Vietnam. *Anopheles quadrimaculatus* was the primary vector of the *Plasmodium vivax* (protozoa) in the United States. Antimalarial drugs have been available for more than 50 years and recently scientists in Britain and the United States have cracked the code of the malaria parasite genome, a step that may help boost the campaign against the disease. In 2003, Florida had its largest malaria outbreak in 50 years. There were eight confirmed cases in the West Palm Beach area north of Miami and no deaths.

Dog heartworm (*Dirofilaria immitis*) can be a life-threatening disease for canines. The disease is caused by a roundworm. Dogs and sometimes other animals such as cats, foxes and raccoons are infected with the worm through the bite of a mosquito carrying the larvae of the worm. It is dependent on both the mammal and the mosquito to fulfill its life cycle. The young worms (called microfilaria) circulate in the blood stream of the dog. These worms must infect a mosquito in order to complete their lifecycle. Mosquitoes become infected when they blood feed on the sick dog. Once inside the mosquito the micro filaria leave the gut of the mosquito and live in the body of the insect, where they develop for 2-3 weeks. After transforming twice in one mosquito the third stage infective larvae move to the mosquito's mouthparts, where they will be able to infect an animal. When the mosquito blood feeds, the infective larvae are deposited on the surface of the victums skin. The larvae enter the skin through the wound caused by the mosquito bite. The worms burrow into the skin where they remain for 3-4 months. Microfilariae are deposited in the blood of the chambers of the right side of the heart and pulmonary artery. They are carried through the lungs, into the left chambers of the heart, and into the systemic circulation. The adult worms are quite large, measuring up to 10 inches long, and they typically live in the dog's pulmonary artery and "right" heart. The female worms produce microfilariae that are found in the dog's blood; demonstration of microfilariae in blood is the primary method of diagnosis. The microfilariae are ingested by a mosquito when it feeds, the microfilariae mature into infective juveniles in the vector, and the infection is transmitted to a new host when the mosquito feeds. If the worms have infected an unsuitable host such as a human, the worms usually die. The disease in dogs and cats cannot be eliminated but it can be controlled or prevented with pills and/or injections. Some risk is present when treating dogs infected with heartworms but death is rare; still prevention is best. Of course good residual mosquito control practices reduce the threat of mosquito transmission. Until the late sixties, the disease was restricted to southern and eastern coastal regions of the United States. Now, however, cases have been reported in all 50 states and in several provinces of Canada.



Arthropod-borne viruses (**arboviruses**) are the most diverse, numerous and serious diseases transmitted to susceptible vertebrate hosts by mosquitoes and other blood-feeding arthropods. All arboviral encephalitides are zoonotic, being maintained in complex life cycles involving a nonhuman primary vertebrate host and a primary arthropod vector. These cycles usually remain undetected until humans encroach on a natural focus, or the virus escapes this focus via a secondary vector or vertebrate host as the result of some ecologic change. Humans and domestic animals can develop clinical illness but usually are "dead-end" hosts because they do not produce significant viremia, and do not contribute to the transmission cycle. There are several virus agents of **encephalitis** in the United States: West Nile virus (WN), eastern equine encephalitis (EEE), western equine encephalitis (WEE), St. Louis encephalitis (SLE), La Crosse (LAC) encephalitis, dengue and yellow fever all of which are transmitted by mosquitoes. Another virus, Powassan, is a minor cause of encephalitis in the northern United States, and is transmitted by ticks. A new Powassan-like virus has recently been isolated from deer ticks. Encephalitis is global, in Asia, for example, about 50,000 cases of Japanese encephalitis (JE) are reported annually.

Dengue is a serious arboviral disease of the Americas, Asia and Africa. Although it has a low mortality, dengue has very uncomfortable symptoms and has become more serious, both in frequency and mortality, in recent years. *Aedes aegypti* and Ae. *albopictus* are the vectors of dengue. The spread of dengue throughout the world can be directly attributed to the proliferation and adaptation of these mosquitoes. Over the last 16 years dengue has become more common, for example; in south Texas 55 cases were reported in 1999 causing one death. More recently, Hawaii recorded 85 cases of dengue during 2001. In 2003, El Salvador reported 879 cases of Dengue or dengue hemorrhagic fever (DHF) and 4 deaths. In 2003 Dengue was reported in Bangladesh, India and in the Americas as well as other areas. Brazil reported over 350,000 cases and 42 deaths.

In 2004 Venezuela has reported more than 11, 600 cases classic dengue fever and over 700 cases of DHF. Indonesia dengue outbreak has caused over 600 deaths and more than 54,000 cases. Laredo, Texas reported the 1st confirmed case of dengue in Texas this year (2004). In 1999, Laredo and Nuevo Laredo had an outbreak of almost a 100 cases. Sri Lanka has reported 24 deaths and 4348 cases this year (2004).

Yellow fever, which has a 400-year history, occurs only in tropical areas of Africa and the Americas. It has both an urban and jungle cycle. It is a rare illness of travelers anymore because most countries have regulations and requirements for yellow fever vaccination that must be met prior to entering the country. Every year about 200,000 cases occur with 30,000 deaths in 33 countries. It does not occur in Asia. Over the past decade it has become more prevalent. In 2002 one fatal yellow fever death occurred in the United States in an unvaccinated traveler returning from a fishing trip to the Amazon. In May 2003, 178 cases and 27 deaths caused by yellow fever were reported in southern Sudan. In the Americas 226 cases of jungle yellow fever have been reported with 99 deaths.

EEE (eastern equine encephalitis) is spread to horses and humans by infected mosquitoes. It is among the most serious of a group of mosquito-borne arboviruses that can affect the central nervous system and cause severe complications and even death. EEE is found in North America, Central and South America, and the Caribbean. It has a complex life cycle involving birds and a specific type of mosquitoes including several *Culex* species and *Culiseta melanura*. These mosquitoes feed on infected birds and become carriers of the disease and then feed on humans, horses and other mammals. Symptoms may range from none at all to a mild flu-like illness with fever, headache, and sore throat. More serious infections of the central nervous system lead to a sudden fever and severe headache followed quickly by seizures and coma. About half of these patients die from the disease. Of those who survive, many suffer permanent brain damage and require lifetime institutional care. There is no specific treatment. A vaccine is available for horses, but not humans.

SLE (St. Louis encephalitis) is transmitted from birds to man and other mammals by infected mosquitoes (mainly some *Culex* species). SLE is found throughout the United States, but most often along the Gulf of Mexico, especially Florida. Major SLE epidemics occurred in Florida in 1959, 1961, 1962, 1977, and 1990. The elderly and very young are more susceptible than those between 20 and 50. During the period 1964-1998 [35 years] a total of 4478 confirmed cases of SLE were recorded in the United States Symptoms are similar to those seen in EEE and like EEE, there is no vaccine.

LAC (La Crosse encephalitis) is much less common than EEE or SLE, but occurs in all 13 states east of the Mississippi, particularly in the Appalachian region. It was reported first in 1963 in LaCrosse, Wisconsin and the vector is thought to be a specific type of woodland mosquito (*Aedes triseriatus*) called the tree-hole mosquito, with small mammals the usual warm-blooded host. It occurs in children younger than 16 and once again there is no vaccine for LaCrosse encephalitis.

WEE (western equine encephalitis) was first recognized in 1930 in a horse in California. It is found west of the Mississippi including parts of Canada and Mexico. The primary vector is *Culex tarsalis* and birds are the most important vertebrate hosts with small mammals playing a minor role. Unlike LAC it is nonspecific in humans and since 1964 fewer than 1000 cases have been reported. As with EEE, a vaccine is available to protect horses against WEE, but no vaccine has been developed for humans. In Arizona, chicken flocks have tested positive in 6 counties.

West Nile virus (WNV) emerged from its origins in 1937 in Africa (Uganda) into Europe, the Middle East, west and central Asia and associated islands. It is a *Flavivirus* (family Flaviviridae) with more than 70 identified viruses. Serologically, it is a Japanese encephalitis virus antigenic complex similar to St. Louis, Japanese and Murray Valley encephalitis viruses. Similar to other encephalitises, it is cycled between birds and mosquitoes and transmitted to mammals (including horses) and man by infected mosquitoes. WNV might be described in one of four illnesses: West Nile Fever might be the least severe in characterized by fever, headache, tireness and aches or a rash. Sort of like the "flu". This might last a few days or several weeks. The other types are grouped as "neuroinvasive disease" which affects the nervous system; West Nile encephalitis which affects the brain and West Nile meningitis (meningoencephalitis) which is an inflammation of the brain and membrane around it.

It first appeared in North America in 1999 in New York (Cornell Environmental Risk Analysis Program) with 62 confirmed cases and 7 human deaths. Nine horses died in New York in 1999. In 2001, 66 human cases (10 deaths) were reported in 10 states also, it occurred in birds or horses in 27 states and Washington D.C., Canada and the Caribbean. There were 733 horse cases in 2001 with Florida reporting 66% of the cases; approximately 33% were fatal. In 2001 more than 1.4 million mosquitoes were tested for WNV. In the United States (2004) over 43 species of mosquitoes have tested positive for WNV infection, the *Culex pipiens* group seems the most common species associated with infecting people and horses.

Since its introduction in New York, WNV has steadily moved westward As of March 2004, West Nile virus has been documented in 48 states and the District of Columbia. In Nevada, the Animal Disease Laboratory has been conducting surveillance testing for WNV on a variety of species since March of 2001. WNV was first confirmed in Nevada on July 16, 2004 with the submittion of a dead bird (a crow), with Nevada's first human cases being confirmed in Clark and Washoe counties in July 2004.

Survey Methods

One of the most important elements of a successful control program is the survey. Surveillance is the detection of the mosquito problems, the species involved, their numbers, and their location. The information provided by survey programs and a thorough knowledge of the mosquito's biology, habits and habitats will provide a sound basis for control. Each problem is different and requires a different approach. Besides providing the immediate information on whether the particular problem warrants control and the methods of control to be employed, analysis of survey data on a long term basis will determine whether the control program is effective. The decision of where to apply the control measures should always be based on surveys.

- **Larval Surveys**

Since the larval and pupal stages of mosquitoes live in water, it's customary to examine the water to determine either the abundance and/or the species of immature stages. A record of the life stages present when surveys are made is important, because pupae and eggs are not readily controlled by chemicals. A long handled water dipper is used to survey for larvae and pupae. The surveys must be made to determine in which waters there are larvae, because the mere presence of water doesn't necessarily mean the presence of mosquito larvae. No water should be treated unless it contains larvae. The frequency of examination for the survey is related to the length of time and the season necessary for larvae to mature.

During the early spring, larval development may take from two to three weeks, but during warm summer temperatures, eggs may hatch and adults emerge in seven to ten days. Because the larvae grow rapidly, the timing of surveys is exceedingly important, especially in the high country. As soon as there is free water from the melting snow and ice, the overwintering eggs hatch into larvae. Mosquito larvae from these overwintering eggs can develop into adults as early as May.

- **Adult Surveys**

There are three main methods of surveying the adult mosquito population: landing counts, light traps, and $C0_2$ traps. Supplementary methods include pigeon traps; resting stations, both artificial and natural; and truck mounted traps moving through mosquito areas.

Landing counts involve rolling up a pant leg or shirt sleeve and collecting the number of mosquitoes that land during a given period of time. These collections give an index of the numbers of the biting population and identify the species causing the most annoyance. The same procedure should always be followed so comparisons between counts can be made.

When surveying mosquitoes for vector potential or for further identification, the mosquitoes which land may be captured with a killing tube or an aspirator. A killing tube is merely a tube or vial whose bottom inch is filled with a killing agent such as ethyl acetate and covered with cotton. When the mosquito lands, the killing tube is placed over the mosquito until it dies. When mosquito populations are high, capturing specimens with an aspirator is a quicker and more effective method than using a killing tube. An aspirator consists of a 12 inch long, one-half-inch-diameter tube with a siphon hose attached to one end. A screen is fitted between the tube and the hose to prevent inhalation of the specimens. Mosquitoes are drawn into the aspirator as the collector draws air through the hose. Specimens are then transferred to a killing tube for further identification. The landing count method samples that portion of the female mosquito population which is seeking blood.

Light traps are a second and typical method of making a mosquito adult survey. This is a metal cylinder with a protective metal cap and containing a light bulb, which serves as an attractant. A fan inside the cylinder blows the insects down into a killing jar or some other collecting container. Both males and females are collected. The number of individuals and species collected gives an index to mosquitoes present in a given area. Not all species are attracted to the light, so the light trap method has limitations.

The light trap should be mounted with the light about six feet from the ground and 30 feet or more from buildings, in open areas near trees and shrubs. Strong winds, competing light sources, or industrial smoke or fumes reduce the light trap's effectiveness. A timer or electric eye can be used to turn the light on and off. Collections should be made daily, and the catch identified and recorded.

$C0_2$ (carbon dioxide) traps are similar in construction to the light trap. The difference is that an insulated container with small holes in the bottom is used either in addition to or in place of the light. The blood meal seeking female follows the $C0_2$ trail produced by the conversion of dry ice into carbon dioxide gas.

Control

Once the situation has been surveyed, a control plan may be formulated. The word "abatement" is often used rather than control since the usual program is designed to reduce the number of mosquitoes to an acceptable level, rather than trying to kill the last remaining individual. Such a practice would be very expensive as well as environmentally unacceptable, in that excessive drainage or use of chemicals would be called for.

An abatement situation may be relatively simple or rather complex, depending on the scope of the problem. There may be a localized adult problem, for instance in a Boy Scout camp, where the adults have emerged from woodland pools that have since dried up. A good residual application of pesticide may be all that is necessary. On the other hand, a community may be surrounded by grass meadows that are flood irrigated. In this case, an integrated abatement program, including water management, physical changes, biological control, and chemical application, would be necessary. Total reliance on pesticides is seldom the best approach. Each situation is different and must be handled differently. Small area abatement situations can be adequately handled by an individual; large abatement programs must be under the strict supervision of a trained director.

- **Larval Control**

Under most conditions, control procedures against mosquitoes are most effective and economical when designed to eliminate larvae. Since mosquito larvae live only in water, water management is a means of control. Where water can't be managed, chemical control may be used. Water management is normally thought of as being a more permanent control measure, whereas chemical control is normally only a temporary measure. The presence of water doesn't always mean that mosquito larvae are present.

Water management on a large scale involves the alteration of the land surface, drainage ways, or ponds and lakes in order to eliminate excess surface water which may serve as mosquito breeding habitats. Water management should be especially considered when a mosquito problem area requires many chemical treatments each year. Although the initial cost of water management may be higher, it may prove less expensive in the long run than repeated insecticide applications.

The control of mosquito populations by the use of water management techniques is directed toward the aquatic stages. The three basic principles involved in water management are:

1. The removal of excess surface water within five days, thereby eliminating the mosquito breeding habitat.
2. Increasing the amount of standing water to create a suitable habitat for predaceous fish and/or creating a means of access for these fish into and out of mosquito breeding areas. In some areas of the state (i.e. Clark County and Washoe County), mosquito fish (*Gambusia spp.)* are commonly used for mosquito control. The Nevada Department of Wildlife (NDOW) has regulations that control the movements of certain fish species which include the *Gambusia spp*. In 2004, via NDOW permits, Clark and Washoe County Vector Control agencies had made available *Gambusia spp*. for mosquito control.
3. Increasing the movement of water in the mosquito breeding area and thus creating stress conditions for the larval and pupal mosquitoes.

Water management on a small scale involves the individual homeowner, but this is important to the success of community programs. Large numbers of mosquitoes can be produced in local, small water accumulations. Especially with species that fly only short distances, homeowners may be able to alleviate their own and their neighbor's problem by the following steps:

1. Eliminate all temporary water containers such as tin cans and old tires.

2. Tightly cover all cisterns, water barrels, cesspools, and septic tanks. Don't allow sewage or other liquid wastes to collect on the ground.

3. Empty, wash and refill bird baths and animal watering containers at least once a week.
4. Keep rain gutters clean and flat roofs dry.

5. Drain or fill stagnant pools or swampy places.

6. Make weekly examinations of the containers in which plants are grown in water. If larvae are seen, dump the water, wash the plant roots and the containers, and refill the containers with clean water.

7. Keep the margins of small pools or ponds clear of plants that emerge through the water.

8. Fill all tree holes with cement, or drain them.

Water management techniques include the general maintenance of existing drainage ditches, streams, and rivers and is essential in any upland water management program. The elimination of debris that normally accumulates in these watercourses is necessary to avoid creating mosquito breeding habitats.

Restoration of some rivers, streams, and ponds is important in maintaining a system that is free of mosquitoes. Many rivers and streams have a flood plain which may accumulate standing water after a heavy rain, thereby providing suitable mosquito breeding habitats. Successful restoration projects involve the removal of any excess surface water by providing outlets to and for tributary streams. Restoration of ponds usually entails the removal of aquatic vegetation and/or the excavation of silt to a depth that will maintain an adequate population of fish and other mosquito predators.

Another source reduction technique involves filling in or grading mosquito breeding areas. Landfills function similarly on a larger scale. The removal of standing water from cans, bottles, tires, and wrecked automobiles such as those found in junkyards -- or preventing such situations -- may substantially reduce mosquito populations. Around dwellings, mosquitoes may be reduced by periodically removing the water from birdbaths, wading pools, or other receptacles which may hold water.

Biological control has already been discussed under water management. Mosquito fish, *Gambusia affinis*, are predatory on larvae and pupae and can be introduced into breeding areas, where they reproduce rapidly. State and local fish and wildlife agencies should be notified before movement or placing non-native fish. Other naturally occurring predators such as diving beetles and dragonfly larvae can be preserved by careful planning and reduced chemical application.

♦ Larvicides and Their Application

Types of Larvicides

Insecticides that kill larvae and, less often, pupae can be applied to water in which the aquatic stages live. Different formulations are used, depending on the situation and application equipment. Formulations include granulars, emulsifiable concentrates, solutions and oils. Application equipment varies from simple granule spreaders or compressed air sprayers to airplanes, again depending on the situation.

Extreme care and adequate supervision are essential when using chemical pesticides to control mosquito larvae. In some areas, water containing mosquito larvae in the early spring may produce only one brood; hence, one well timed application of a suitable pesticide in the spring is sufficient. In some communities, other species produce several broods throughout the summer months, and a pesticide may be required to control each brood. Because of these differences in mosquito biology, a continuing survey is necessary to determine when the larvae are present in sufficient numbers to justify control procedures.

In large ponds and lakes, almost all larvae are found among the marginal emergent vegetation, so little or nothing will be gained by treating the open water. The pesticides should be applied only to the weedy margins. By limiting the treatments to these areas, the danger of harming fish and other desirable organisms will be reduced.

- **Granular Larvicides**

Granular formulations sink to the bottom of larval breeding areas and release the toxicant into the water. Granular formulations can be applied as a pre-emergence treatment over ice in marshes or woodland pool areas in the very early spring. At this time, all areas of the marshes are accessible. Later, after the ice melts, coverage of the marsh may be difficult. When the ice and snow melts, the insecticide is released.

Granular materials are also advantageous for spot treating small pools in sensitive areas such as bird sanctuaries, where a broadcast treatment would be environmentally unacceptable. When aerial applications must be made to large areas under heavy foliage, granulars are especially effective, since they won't stick to the foliage, but will bounce down through it and into the water. Most of the pesticide will reach the target instead of a large proportion remaining on the leaves, as would be the case if a liquid spray were used.

- **Oils**

Light, highly refined oils designed especially for mosquito control are applied to the water surface and spread in a thin film over the water. They act on both larvae and pupae either by suffocating the insects or by poisoning them as they take in toxic vapors through their breathing tubes.

Application: Application rates vary from one to ten gallons per acre, depending on the type of oil, the vegetative cover, etc. The oils are relatively safe to other forms of wildlife and can be used in sensitive areas where other larvicides are not suitable. Oils are usually used to control pupae.

Oils are usually applied by compressed air sprayers, power sprayers, or aerial equipment.

Oil Solutions: Oil solutions are often supplied by the manufacturer in highly concentrated form. Many of the chemicals used against mosquito larvae are so effective that only a small amount is required for control. One twentieth of a pound (.05 pound) per acre may be all that is needed or recommended. It's hard to apply this small amount uniformly over an area, so the manufacturer's concentrate is often diluted with oils for easier handling. Oil based solutions don't evaporate as quickly as water emulsions, so they are preferable when the applicator depends on drift to help cover the area to be treated.

Oil solutions are often applied to small breeding areas with compressed air sprayers or portable mist blowers and to larger areas with mist blowers or aerial equipment.

- **Emulsifiable Concentrates**

Emulsifiable concentrates are designed to be diluted with water. The insecticide will mix with the water in the breeding area and control larvae present. They can be applied with hand equipment such as compressed air sprayers or with power sprayers. Aerial application can also be used, but since the water based mixture in tiny droplets evaporates rather quickly, this type of equipment is generally not as satisfactory.

- **Growth Regulators**

Similar in formulation and application techniques to other larviciding chemicals. However, they differ in their mode of action. Other chemicals usually used kill the mosquito larvae or pupae, but growth regulators interfere with the normal development of the insect. The mosquito larva may never transform to a pupa, or molting may be affected. Growth regulators are desirable in that they have little or no effect on other wildlife occurring within the breeding area.

Application Equipment

Granule applicators, whether large or small, all work on the same principle. They are containers with adjustable openings in the base through which a controlled amount of granular insecticide may pass. They may be manually operated or power assisted. Some may be equipped with agitators or auger feeds to help produce a uniform flow.

- **Horn Seeders**

The simplest device for applying granules is the horn seeder. The horn seeder is comprised of a canvas bag which is slung over the shoulder with a tapered, telescoping wand or tube located at the lower front corner of the bag. Granules are dispersed as the operator's arm and wand move in a horizontal figure eight fashion. Application rates may be altered by adjusting the opening at the base of the wand or by changing the speed at which the operator walks.

- **Cyclone Type Spreaders**

The cyclone type spreaders are the second type of manually operated granular applicators.

These are cylinders with an adjustable slot in the base through which granules fall onto a rotating disc and are dispersed by centrifugal force. This disc is rotated by gears, which are activated by turning a crank handle. The rate of dispersal may be altered by controlling the size of the slotted opening or by changing the walking speed of the operator.

Both the cyclone type spreader and the horn seeder are commonly used in treating small, isolated breeding areas such as woodland pools.

- **Blower Type Applicators**

The power assisted, blower type granular applicators have feed tubes which meter the granules into the blast of an air blower. These blower type spreaders may be backpack size or truck mounted. The speed of the air blast ranges from 75 to 150 miles per hour. Similar blower type spreaders are also used in helicopter delivery systems where the forward air speed of the aircraft isn't high enough to provide adequate pressure for proper distribution of the granules. In fixed wing aircraft, where the payload is greater, ram air type spreaders are used which require no power other than the air being driven back by the propeller.

Liquid larvicides most often used are oils, oil solutions or emulsions. The choice of formulation is influenced by the application equipment, the distance the material is expected to drift, the safety of the formulation, and other such factors.

Liquid application equipment used in larviciding varies from simple hand equipment to truck mounted sprayers and specially equipped aircraft. The largest equipment isn't always the best. Rather, equipment should be chosen to fit the situation. A description of commonly used types follows:

- **Compressed Air Sprayers**

One of the most common sprayers for treating small areas is the one to three gallon compressed air sprayer. The air in the upper portion of the spray tank is put under pressure by a hand pump, and the pressure created forces the spray through the nozzle. Compressed air sprayers are used for applying larvicides to small breeding areas such as catch basins or woodland pools.

- **Hydraulic Sprayers**

In hydraulic sprayers, the spray mixture is taken into the pump, put under pressure, and forced through the nozzle. In some sprayers, pressures of up to 600 psi may be reached. Hydraulic sprayers range in size from a backpack with a trombone sprayer to those which are truck mounted. This equipment is most often used for treating larger mosquito breeding areas.

- **Aerial Sprayers**

Liquid spray systems can be mounted on either fixed wing or rotary wing aircraft and make larviciding of large or otherwise inaccessible areas easy. Regular spray delivery systems can be nozzled to apply the rather small quantities needed per acre.

■ Adult Control

While larval control is the preferred method of treatment when possible, there are situations where it can't be used or where adulticiding supplements a larviciding or integrated program. Sometimes a larval population escapes control, and the biting adults must be reduced. If a small village is surrounded by many acres or miles of breeding area, usually larviciding isn't economically possible. The same holds true for small areas such as outdoor theaters, camps, racetracks, parks, and individual properties. Sometimes an adult population that has been only a nuisance will become a public health problem as a disease vector and must be drastically reduced. All of these situations require adult mosquito control.

Space Treatments: Insecticides used in space treatments are applied as fine droplets in the form of fogs, mists, or fine sprays. The droplets float about in the air, settling very slowly and, depending on their size, drifting over long distances to expose adult mosquitoes to the insecticide. Drift is both a help and a hindrance. It helps control mosquitoes over a large area, but the application must be planned to avoid highly sensitive areas, for instance bee yards, fish ponds or parking lots, especially if the droplets are large enough to settle into these areas.

Space treatments are temporary, becoming ineffective as soon as wind has carried the droplets out of the area. Winds exceeding five or six miles per hour or temperatures of more than 85 degrees F. often reduce the effectiveness of the insecticide. Application is best made in early morning, early evening, or at night, when the air is calm and cool. Larger droplets that are deposited on foliage may give short residual action.

Application equipment for space treatments varies from hand carried equipment to truck mounted or aerial delivery systems. Different types of units include ultra low volume (ULV) applicators, thermal foggers, cold foggers, mist blowers, and aerial dispersal systems.

1. In **ULV equipment**, low pressure/high velocity air and low pressure liquid insecticide concentrates are introduced into a swirl chamber, where shearing action of the air produces extremely fine droplets. Droplet size is relatively uniform and controllable. ULV with ground equipment is becoming increasingly popular for space treatments. Units are either portable or truck mounted. Treatments rely on a gentle wind (one to five miles per hour) to carry chemical to the target area.

2. Thermal foggers produce an insecticidal fog formed by momentarily exposing the spray concentrate to heat. A heavy cloud of smoke is produced, which contains very fine particles of insecticide. Thermal fogs are very susceptible to wind and thermal air currents. If applied during unfavorable conditions, such as during a hot day, the fog may be carried up and over the target adults and be ineffective. It's usually better to do applications during the evening or at night, when the fog is more likely to be held close to the ground. Thermal fogging was once the main form of mosquito adulticiding, but

because the thick clouds can be hazardous to traffic, it has been replaced with ULV.

Foggers range from small hand held units that use blowtorch propane bottles for their heat source to larger units that must be carried in a pickup truck. Units that use the hot exhaust gases from jeep, truck or helicopter exhausts have been successfully used.

3. **Cold foggers** have characteristics similar to thermal foggers, except that the fog results from a mechanical breakup of the spray concentrate.

4. **Power sprayers or hand held compressed air sprayers** are used to apply residual adulticides to perimeter vegetation, sometimes referred to as barrier spraying.

5. **Aircraft** can quickly and effectively apply space sprays over large areas. This is especially desirable if a public health problem such as encephalitis suddenly appears, or if a large population of nuisance mosquitoes escapes. Because of the high application speed, ULV techniques can be easily used. However, drift problems will be magnified. Small orifice conventional nozzles or specialized high rpm spinning nozzles are used.

All adulticide applications are much more effective when a temperature inversion exists in the lower 30 feet of the atmosphere.

Storm sewer or catch basin treatment is an important part of a community program.

In cities with catch basins along the edges of streets, surveys indicate that many basins hold enough water to produce large broods of house mosquitoes. The application of petroleum oils or granular insecticides to these catch basins is useful but isn't always the complete answer to this type of mosquito control. A single shower may produce enough runoff to flush out the larvicide.

Dilute residual sprays can be applied with compressed air, knapsack or powered hydraulic sprayers. Concentrated residual sprays are applied by mist blowers.

Resistance to Insecticides

The resistance of both larvae and adults to insecticides is always in a state of change. Some species of mosquitoes are resistant and some are not. To make matters more complex some resistant species may be non-resistant in some areas. It is well known that all insects have the biological capability of developing resistance to all insecticides. With resistance always a consideration, alternating chemicals throughout the season is advisable. Researchers are constantly searching for new control agents and methods to keep ahead of our mosquito enemies.

Gambusia and mosquito control

Gambusia holbrooki and *particularly G. affinis* (Cyprinodontiformes: Poeciliidae) are native to southern and eastern USA, but now (following translocation) have an extensive global distribution. Where mosquito-borne diseases pose a threat to human health, and native fish are not suitable control agents stocking water bodies with poeciliids (such as gambusia and guppies *Lebistes reticulatus*) may be one of the few means of mosquito control. These poeciliids are well-suited to stagnant waters, where they tend to remain stationary just below the water surface, using the relatively oxygen-rich interface layer. However, the effectiveness of gambusia as a mosquito control agent is unclear. Gambusia may prefer to consume macro-invertebrates other than mosquito larvae (particularly large instars). Some of these macro-invertebrates consumed may include species which also prey on mosquito larvae. Gambusia, not having the aestivation/embryonic diapause capability of some Cyprinodontiformes, die out in seasonal ponds, requiring a restocking program.

Two thing must be taken into consideration before using *Gambusia* fish:

1) Use locally adapted stock.
2) Contact the Nevada Depatment of Wildlife before moving fish. In some instances, depending on existing transportation permits, NDOW may require that an individual obtain a transportation permit to move mosquito fish (*Gambusia spp.)* from one water body to another water body within Nevada. In Clark County and Washoe County, the vector control agencies commonly obtain a transportation permit from NDOW for the movement of mosquito fish (*Gambusia spp.)* for mosquito control, within their jurisdictions. For more information on the movement of mosquito fish, contact the Supervising Fisheries Biologist for NDOW at 1-702-486-5127 or via the internet at www.ndow.org or www.nevadadivisionofwildlife.org.

Endangered Species Concerns

If you are attempting mosquito control in White Pine, Lincoln, Clark or Nye Counties be aware that there are several endangered species in these counties and that there are restrictions as to the chemicals that can be used and where they can be applied. This information can be obtained from the product label, US Fish and Wildlife Service, Cooperative Extension, and or the Nevada Department of Agriculture.

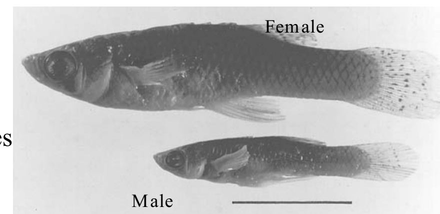
Mosquito fish

Gambusia affinis

This small Texas native is only two to two and a half inches long and can now found throughout the world. It has been introduced in many places to eat mosquitoes that cause malaria. Unlike most fish, the Mosquito fish does not lay eggs, but instead gives birth to live young.

Appearance

- Length: Up to 65mm (2.5 inches) for females.
- Up to 35mm (1.3 inches) for males.
- Distinguishing Characteristics:
  - Guppy-like body shape
  - Dull gray, but females have large dark spot on sides
  - Upturned mouth for feeding on the surface
  - Male has long, flexible fin (called a gonopodia) to Fertilize eggs inside the female's body



Scale bar: 1 cm.

Behavior

- Habit: Swims near the surface close to shoreline in well-vegetated waters
- Diet: Omnivore. Feeds mostly on mosquito larvae and pupae, but also eats algae, zooplankton, and small invertebrates and fishes.
- Range: Southeastern United States to northern Mexico.
- Introduced in other places around the world.
- Lifespan: Probably not much more than one year.

Habitat

- The Mosquito fish lives in warm water with little or no current and prey species are abundant.
- Prefers to live near the shoreline in waters with plenty of aquatic plants.
- Can survive in water too hot for most other fish species.
- Can take oxygen from the surface and so can live in poorly oxygenated waters.
- Can live in brackish waters.
- Will also live in drainage ditches.

Life Cycle

Sexual Maturity: Mosquito fish born early in the spawning season can reach maturity and reproduce in the same season. Those born later will mature by the next spawning season.

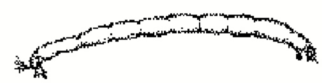
Spawning Season: Spawning begins in the warm months of spring and continues through early fall. Males use a specialized fin (gonopodia) to fertilize the eggs still inside the females body. Females carry anywhere from one to more than 300 embryos and may produce 5-10 broods per season. Newborn Mosquito fish fend for themselves immediately after birth.

Gestation: 21-28 days

MIDGES

Midge elimination methods, biology and identification of midges.

Introduction



This fly belongs to a family of small to moderately large flies. People are often alarmed by midges or chironomids since they resemble mosquitoes. However, they differ from mosquitoes in that the wings are not scaled and the mouthparts are short and not adapted for biting. Adult midges are slender, usually less than 5 mm long with long, slender legs and wings. Midges lay their eggs on water. The larvae are usually aquatic, are found in quiet water such as lakes, ponds, reservoirs and tanks, and are bottom feeders. Polluted water apparently favors their growth and development. In the summer, eggs will hatch in about 3 days and larvae will reach adulthood in about 4 weeks.

During peak emergence, large numbers of midges fly into residential and industrial areas causing annoyance and damage. They are attracted to lights at night and thousands will rest on the outside of buildings and will enter homes through the slightest crack. They fly into people's eyes, ears and mouths and are sometimes inhaled.

Midge Facts:

- Almost 2000 species in North America.
- Are found in all but the most polluted aquatic conditions.
- Presence in large numbers may indicate organic enrichment.

Midge Description:

- Up to ½ inches long.
- One pair of tiny, fleshy legs below the head and one pair on the back end.
- The back end sometimes has a tiny pair of extensions that look like brushes.
- A thin dark line (digestive tract) can be seen inside the body.
- Thin, slightly curved, segmented and inch-worm-like body.
- Distinct, often dark head.

Beneficial Aspects

Most species of chironomid midges are highly desirable organisms in aquatic habitats. Midges are an important food source for fish and predatory aquatic insects. Larvae "clean" the aquatic environment by consuming and recycling organic debris.

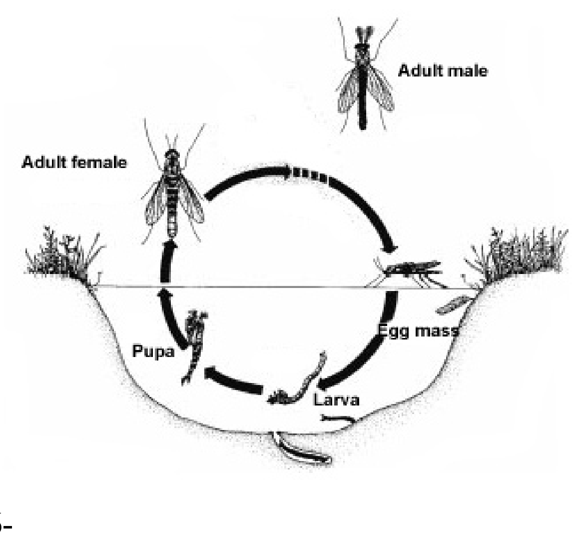
Economic Impacts

In urban environments where homes are constructed adjacent to lakes and ponds, adult midges often emerge in extremely large numbers, causing a variety of nuisance and other problems for people who reside within the flight range of these insects. Adults are weak flyers and may fly or be blown ashore where they congregate on vegetation, under porch alcoves in carports and on walls of homes and other buildings. Swarms of adults may be so dense that they interfere with outdoor activities and stain walls, cars and other surfaces upon which they rest. Adults are attracted to lights and may accumulate in large numbers on window screens and around porch and street lights. The occurrence of midges promotes the growth of spiders whose unsightly webs may have to be removed frequently.

Life Cycle

There are four stages in the life cycle of chironomid midges. Eggs are laid on the surface of the water. Each gelatinous egg mass may contain up to 3,000 eggs depending on the species. Eggs sink to the bottom and hatch in several days to one week. After leaving the egg mass, larvae burrow into the mud or construct small tubes in which they live. Larvae enlarge their tubes as they grow. Suspended organic matter in the water and in the mud is used as food by the developing larvae. After they grow, the larvae take on a pink color and gradually turn a dark red. Consequently, mature larvae are commonly called "blood worms". The red color results from an iron containing compound, hemoglobin, that is in the midge's blood. The hemoglobin allows the larvae to respire under low dissolved oxygen conditions in the bottom mud. The larval stage can take from less that 2 to 7 weeks depending on water temperature. Larvae transform into pupae while still in their tubes. After 3 days, pupae actively swim to the surface, and adults emerge several hours later. Adults mate in swarms soon after emerging. Because they do not feed, adults live for only 3 to 5 days.

During summer, the entire life cycle from egg to adult can be completed in 2 to 3 weeks. In the fall, larvae do not pupate, but they suspend development and pass through the winter months as mature larvae. Pupation and emergence of adults occurs the following spring in late March or early April. Several more generations of midges will be produced throughout summer, resulting in mass emergences of adults. In each generation, adults will typically emerge in large numbers for several weeks.



Breeding Sites

Chironomid midges are one of the most common and most abundant organisms in natural and man-made aquatic habitats. Larvae are found in small and large natural lakes, sewage oxidation and settling ponds, residential lakes and ponds, and slow moving shallow rivers. Densities of over 4,000 larvae/ft^2 often occur on the bottoms of nutrient rich bodies of water. During emergence periods, it is not unusual for several thousand adults per square yard of surface to emerge on a nightly basis. Needless to say, midges emerging from these bodies of water may cause severe nuisance and other economic problems.

Control Measures

Physical and Cultural

Nutrient reduction. Reduction of aquatic midge populations can often be accomplished if the physical and chemical environmental factors that are responsible for development of nuisance populations are altered. Since dense larval populations usually occur in nutrient rich habitats, manipulating the nutrients that are introduced into aquatic systems by reducing run off from agricultural operations and urban environments may help to discourage the proliferation of midges.

Winter draw down. Exposure of bottom muds by draining lakes and reservoir during winter months will kill over wintering midge larvae, reducing the size of the adult population emerging in spring. Understandably, this method may not be practical for all bodies of water.

Diversion of adults. Many lakes and reservoirs that produce nuisance populations of midges have homes and businesses constructed along the shore lines. After emergence, midge adults are attracted to shoreline lights. High intensity white light has been found to be highly attractive to adults. Keep window blinds closed and porch light off during heavy emergence periods to help reduce the number of adults attracted to residences. Strategically placed high intensity white lights my divert midges away from populated areas.

Electrocution traps. Electrocutor traps will attract and kill large numbers of midge adults. It is doubtful that a single electrocutor trap could kill a sufficient number of midge adults to appreciably reduce nuisance populations. In addition, during heavy adult activity, the trap may malfunction as a result of becoming clogged with midge body fragments.

Biological

Midges are fed upon by a large variety of aquatic organisms, such as dragon fly nymphs, predaceous diving beetles and a variety of fish species. Where the diversity of predaceous animals is high, the density of midge larvae is usually held below nuisance population levels. Shallow, organically rich lakes and heavily polluted habitats such as sewage waste lagoons are inhabited by few predaceous species compared to bodies of water that receive less nutrient-rich input.

Predatory fish. Chironomid midges are a major component of the diet of many fish species. In particular, bottom-feeding fishes, such as catfish and carp, consume large numbers of midge larvae. However, the feeding of these fishes has, generally, not been shown to reduce adult midge populations below nuisance levels adjacent to habitats where there were large larval populations.

Insecticidal

Larvicides. Granular temephos (Abate®) is registered by the U.S. EPA for control of aquatic midge larvae in standing water habitats. Application of temephos to control chironomid midge larvae should be regarded as a temporary, "stopgap" method. Although application of temephos is an effective treatment for control of chironomid midges, repeated and prolonged use of the chemical may lead to the development of resistance in midge larvae. Currently, residue tolerances for temephos in fish have not been established. Consequently, it is illegal to consume fish that are caught in bodies of water that have been treated with temephos.

Dimilin 25W® is the only available diflubenzuron formulation for mosquito and midge control in Nevada. The product is currently available for use in Nevada as a Restricted Use Pesticide with a Special Local Need (Chapter 24c) Permit granted by the NDOA in 1994 (NV SLN 940003). The toxicity of this compound to crustacea has been measured below 1 ppb and thus natural habitat applications must be avoided. Due to its toxicity to aquatic invertebrate animals, Dimilin 25W® is classified as a Restricted Use Pesticide. The Dimilin 25W® label bears the signal word "CAUTION." When using Dimilin 25W® for mosquito or midge control in Nevada, the Dimilin 25W® Supplemental Label, for Nevada, allowing such use must be in the possession of the applicator at the time of application. A Dimilin 25W® Label and Supplemental label can be found at the web site of the manufacturer Compton/Uniroyal Chemical (http://www.cdms.net/manuf/default.asp).

Dimilin 25W® is distributed in a powder formulation that contains 25% (wt./wt.) diflubenzuron per pound. Dimilin 25W® may be diluted and applied as a wet spray or formulated on site using label instructions and broadcast as 0.25% or 0.50% sand granules. For sites other than intermittently flooded pastures, Dimilin 25W® can be applied at 3.25 ounces per ac. (0.05 lb. AI). In flooded pastures, Dimilin 25W® may be applied at 0.025 to 0.040 pound AI per ac. a maximum of six times per year, and never in floodwater that remains over 21 days.

Dimilin 25W® can be used in freshwater sites where there is a low risk to populations of crabs, shrimp and other non-target arthropods through direct application. Such habitats include street gutters, rubber tires, storm drains, ditches and retention/detention/seepage ponds, sewage effluent and disposal fields and oxidation ponds, grassy swales, phosphate pits, tailing canals and slime ponds, wastewater biological filter beds, industrial-waste tertiary ponds and irrigation disposal fields, livestock, swine, and poultry waste lagoons, artificial ponds, channels and percolation basins designed exclusively for decorative and landscape purposes, and junkyards. It is not to be applied when conditions favor drift or runoff to adjacent aquatic sites.

Dimilin 25W® is cost effective for use in "dirty water areas" where non-target organisms are not present. It has the advantage of killing the target organisms quickly (within 1 molt cycle) and thereby usually allows touch-up work in areas that may have been missed. However, a Dimilin 25W® has its disadvantages; hay or feed for livestock should not be produced from treated pastures treated with Dimilin 25W® . Growers must be informed that the grass is not to be cut for hay. Water treated with Dimilin 25W® may not be used for irrigation or human consumption. Food or feed crops are not to be planted in treated pasture areas within six months following the last application, unless Dimilin 25W® is authorized for use on these crops. Diflubenzuron is extremely toxic to crustacea.

The biological larvicide, *Bacillus thuringiensis* var. *israelensis* (*Bti*), is registered for use against chironomid midge larvae. Unlike temephos which exerts contact toxicity, *Bti* is toxic after being consumed by the larvae. Consequently, in waters of high organic content (which present a competing food source for the midges), *Bti* is only effective at high rates of application (at least 10 times the rates needed for mosquitoes), which limits the economic use of *Bti* to small habitats. To maximize the effectiveness of larvicides, applications should be properly timed. Accordingly, dredge samples of bottom mud should be collected, sieved, and the chironomid larvae recovered and counted. Chemical treatments should be made when the number of larvae found equals or exceeds **200 per 6 inch square bottom sample**. This treatment threshold is completely arbitrary. It is based on insecticide treatments made for the control of midge larvae in Florida and California. Without monitoring a midge population for one season, the relationship between numbers of immature midges in the bottom mud and consequent numbers of nuisance adults can not be established.

The insect growth regulator methoprene (*Strike*®) is registered for use in municipal wastewater treatment facilities to control midges and filter flies.

Adulticides. Many insecticides that are registered for the control of adult mosquitoes are also registered for application against non-biting midge adults. Adulticides can be applied in the air as ultra low volume sprays or to wall surfaces or vegetation where midge adults rest. The use of insecticides against adults should be expected to achieve temporary control during heavy emergence periods, because treated areas are rapidly repopulated by midges flying in from outside the treatment zone. Application of residual insecticides to porch alcoves, carports, under the eaves of house and other similar areas should help to discourage the establishment of spiders that are associated with outbreaks of chironomid midge adults.

Black Flies

Black flies are commonly called biting gnats. They are closely related to mosquitoes. Female black flies suck blood in order to develop eggs. Males do not bite but feed on plant nectars. Female black flies range in size from an eighth to a quarter of an inch.

The painful, itchy bite of the black fly is characterized by a reddened weal with a wound in the center. The wound is created by the female when she cuts a hole in the skin to suck the blood that seeps into it. In the process she injects anticoagulants, a pain killer (to remain stealthy!), and some toxins. The pain and swelling of the bite are due to an allergic reaction to these foreign proteins and a response to the toxins. Black flies do not transmit any diseases to humans in Nevada.

Black Fly Life Cycle

Shortly after emergence from their larval breeding site, adult male and female black flies mate. The female then must locate a blood-meal to complete development of her eggs. Egg development is completed in 2-4 days. The female then locates a pond, river or stream in which to lay them. Depending on the species, this will range from the tiniest spring to the Humboldt, Truckee, Colorado or Walker River.

Female black flies generally ambush their victims from tree-top perches near the edge of an open area. They are active during the day with peak activity in the morning and early evening. Females live from one to three weeks, depending on the species and weather conditions. They survive best in cool, wet weather.

When the eggs hatch, the tiny larvae begin their life in the stream. They eat by filtering food from the running water with specially adapted mouth parts that resemble grass rakes. They grow to about 1/4 inch when fully developed. This takes from 10 days to several months, depending on the species and the water temperature. They then enter the pupal stage where transformation to the adult stage takes place. The adult emerges from its pupal case by riding a bubble of air to the surface, much like what happens when you put a ball under water and let it go!

Control Measures

Streams and rivers can be treated with a liquid formulation of *Bti*, a naturally occurring soil bacteria. This bacteria kills larval black flies while they are still in the water. Treatments should begin after sampling shows high numbers of biting gnat larvae developing in rivers or streams.

Parasites and Diseases of Fishes

Fishes in nature have a wide variety of parasites and diseases. Usually these do not have a major impact on the fish populations. When fish are crowded as in the intensive culture of conservation agency fish hatcheries and private aquaculture, parasites and diseases can become serious problems. The best treatment, of course, is prevention. Sound culture management including good quality water and good nutrition will usually result in healthy fish. Healthy fish are usually resistant to diseases. At times parasite and disease problems occur that can best be treated with a chemical. The details of diagnosis and treatment are highly technical and require additional training so they will not be covered here. Few chemicals are registered for use on food fish.

Special Considerations for Exotic Species

The movement of aquatic plants (as well as, vertebrates and invertebrates) across international borders is of considerable quarantine concern. The strong competitiveness of many aquatic plants and animals makes many species of aquatic organisms a serious quarantine concern if they were to be released into waterways and possibly displace native species. Usually, when exotic species are introduced, the natural checks and balances of predators, parasites or competition are not in place, as they would be in their native habitat. Therefore, they become even more competitive. The most common pathway for entry for aquatic organisms into new areas is through discarded aquarium materials followed by water craft being moved from one area to another without proper cleaning.

Many aquarium plants, with origins in the aquarium trade, have subsequently become serious environmental weeds. These include, but are not limited to the water hyacinth (*Eichhornia crassipes*), Salvinia (*Salvinia molesta*), East Indian Hygrophila (*Hygrophila polysperma*), Cabomba (*Cabomba caroliniana*), Hydrilla (*Hydrilla verticillata*) and Asian Marshweed (*Limnophila sessiliflora*). To prevent the introduction of invasive aquatic weeds as aquarium plants into the United States, and to slow their dispersal once introduced, requires correct identification by Federal authorities at entry points, and by local managers once a weed is introduced but is still containable.

Methods of control are determined by the specific species identified. Therefore, as pest management professionals, correct identification of aquatic weeds, vertebrates and invertebrates is essential when thinking about control measures. Many of these introduced weeds, vertebrates or invertebrates may not respond to traditional control methods. If you suspect that you may be dealing with an introduced aquatic weed, vertebrate or invertebrate, contact your local manager (any federal or state office for the locality of the control project) or the NDOA Weed Coordinator in Reno, Nevada at 775-688-1180 for accurate identification and appropriate control measures.

World-wide trade in aquatic organisms for the aquarium and pond hobbies is a multi-million dollar industry. Along with fish, aquatic, semi-aquatic, amphibious plants, and invertebrates are exported largely from tropical and subtropical regions to various countries around the world. While many of the aquatic plants are harvested from the wild, many more are cultivated in large nurseries in countries in warmer regions where the growing period is longer and plants are less costly to cultivate. Aquatic plants come from a wide variety of taxonomic groups and association with aquatic habitats is not restricted to any single plant evolutionary lineage.

Aquatic plants that are associated with water have a remarkable variety of growth forms regardless of their natural history. Strictly aquatic plants (hydrophytes) have an obligate submerged, emergent or floating growth habit and do not grow well out of water. Semi-aquatic (emergent) plants have aerial leaves and stem but require roots to remain submerged or in moist ground. Amphibious plants grow equally well submerged or emersed, and often with distinctly different growth morphology/phenology between both habits. Helophytes are essentially terrestrial plants that tolerate extended periods of time submerged in water but usually live a terrestrial existence.

Aquatic plants live in a highly dynamic and hostile environment characterized by the ephemeral availability of water, constant predation, intense competition for light and nutrients from other plants and algae, and shading by planktonic algae, sediment and water turbidity. Consequently, to be competitive in these environments, aquatic plants are characterized by rapid growth rates, strong chemical allelopathy, and remarkably effective mechanisms for dispersal, including seeds, rhizomes, stolons and detached leaves and shoot nodes which can develop into separate plants.

Appendix A

Aquatic Photographs

Aquatic Plant Pests
Control Measures
Prevention
Aquatic Insect Pests

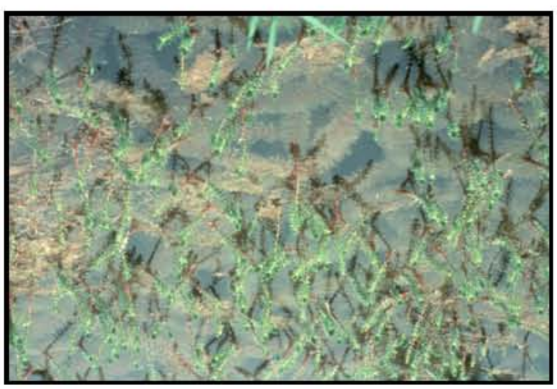
Photo Plates—Page 1


1. Algae & Cattails


2. Arrowhead (*Sagittaria spp.*)


3. Duckweed (*(Lemna spp.*)


4. Duckweed (*(Lemna spp.*)


5. Watermilfoil (*(Myriophyllum spp.*)


6. Purple Loosestrife *(Lythrum salicaria*)

Photo Plates—Page 2

7. Micro Algae or Phyto-plankton

8. Filamentous Algae

9. Coontail (*Ceratophyllum spp.*)

10. Tall Whitetop or Hoary Cress (*Cardaria draba*)

11. Tamarisk or Saltcedar (*Tamarix spp.*)

12. Scotch thistle (*Onopordum spp.*)

Photo Plates—Page 3

13. Bulrush (*Scirpus spp.*)

14. Grass carp (*Ctenopharyngodon idella*)

15. Pondweed (*Potamogeton spp.*)

16. Pondweed (*Potamogeton spp.*)

17. Watermeal (*Wolffia spp.*)

18. Naiad (*Najas spp.*)

Photo Plates—Page 4

19. Hydrilla (*Hydrilla spp.*)

20. Salvinia (*Salvinia spp.*)

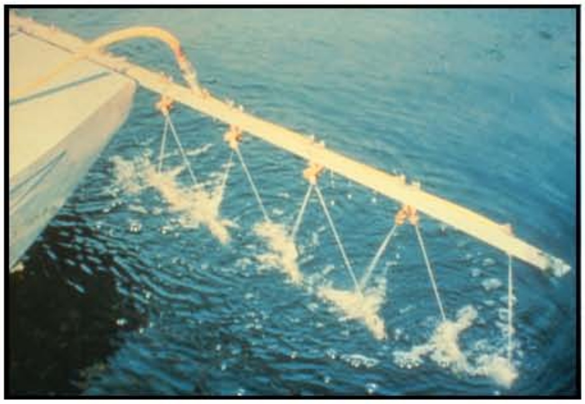
21. Salvinia (*Salvinia spp.*)

22. Chara (*Chara spp.*)

23. Smartweed (*Polygonum spp.*)

24. Smartweed (*Polygonum spp.*)

Photo Plates—Page 5



25. Herbicide application to water

26. Mechanical control - rake

27. Mechanical control - weed harvester

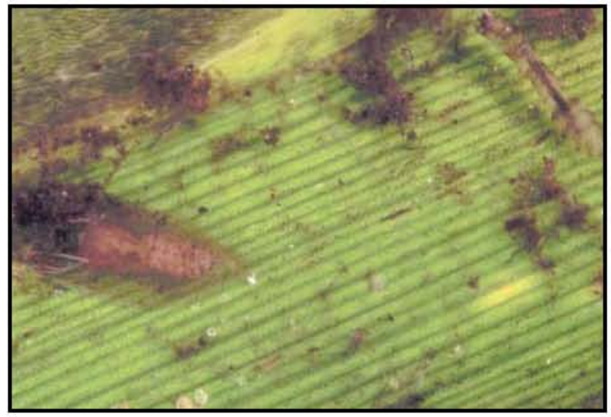
28. Prevention - lined ditch

29. Prevention - vertical walls

30. Prevention - rip rap

Photo Plates—Page 6

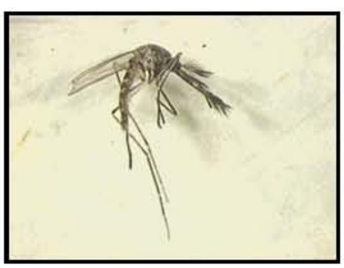
31. Black Fly adult (*Simulium spp.*)



32. Black Fly egg, pupae & larvae (*Simulium spp.*)

33. Midge adult (*Cricotopus spp.*)

34. Midge larvae (*Cricotopus spp.*)



35. Mosquito (*Aedes spp.*)

36. Mosquito (*Anopheles spp.*)

37. Mosquito (*Culex spp.*)

38. Mosquito (*Culiseta spp.*)

39. Mosquito larvae