

# TRADITIONAL PROTECTION AGAINST BITING FLIES

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*Abstract.* Most mosquitoes, biting midges, horse flies, tsetse flies, sand flies, stable flies, and other bloodsucking Diptera are associated as larvae or adults with wetland habitats, but may affect people many kilometers from wetlands. Malaria, African sleeping sickness, onchocerciasis, encephalitis, and other fly-borne diseases affect a substantial part of the world's population. Protection from biting flies is necessary to enable people to use wetland resources. Review of the literature of ethnography and medical entomology reveals a great diversity, here classified, of traditional human tactics of protection against fly bites. Among evidently widespread tactics are: indoor and outdoor smudge fires; herbal repellents; ephemeral, diel, seasonal, or permanent avoidance of certain habitats or regions; fly-tight or elevated living or sleeping quarters; protective clothing; stabling of livestock in proximity to humans to deviate mosquitoes from humans; and modification of hydrology or vegetation in wetland or upland habitats to reduce their suitability to flies. Invoking the factor of fly protection may be useful in understanding human behaviors and culture traits such as fear of the dark, cosmetics, smoking, incense, diet, habitat alteration, and responses to other parasites and diseases.

**KEY WORDS:** Adaptation, cultural; Culicidae; Diptera; disease, water-related; entomology, medical; wetlands

## INTRODUCTION

Worldwide, people obtain needed resources from wetlands, including food, fiber, water, cultivable soils, and refuge from or advantage over enemies (Maltby 1986, Mitsch and Gosselink 1986, Loffler 1990, Kiviat 1991). The ability to use wetland resources and minimize the effects of wetland hazards is shaped by behavioral and cultural adaptations to wetlands. Use of wetlands has costs, including: flood damage; pre-harvest and post-harvest food losses; travel difficulties; natural and artificial toxic substances; and the nuisance and disease transmitted by water and biting flies.

Nine families of Diptera (true flies) contain species which bite and suck human blood: Calliphoridae (blow flies, 1 with a bloodsucking larva), Ceratopogonidae (biting midges), Culicidae (mosquitoes), Glossinidae (tsetse flies), Hippoboscidae (keds, etc., primarily parasites of non-human mammals and birds), Muscidae (including *Stomoxys* stable flies and *Haematobia* horn flies), Phlebotomidae (sand flies), Rhagionidae (snipe flies), and Tabanidae (horse flies). Many of the biting midges, mosquitoes, tsetse flies, stable flies, sand flies, snipe flies, and horse flies are closely associated with wetlands, water margins, or moist soils. Larvae and pupae of biting flies develop in waters of all sizes, sediments of tidal and nontidal wetlands and water edges, decaying bark and leaves, treeholes and other water-holding plant cavities, wet moss, sap leaking from trees, dung, wet hay or crop residues, wet animal feed, compost, shore wrack, bird nests, other concentrated decaying plant matter, and sewage. Some biting midges, mosquitoes, tsetse, stable flies, sand flies, black flies, and horse flies are vectors of viruses, bacteria, protozoa, and nematodes causing human diseases including encephalitis, yellow fever, dengue, bartonellosis, sand fly fever, European relapsing fever, leishmaniasis, leptospirosis, tularemia, anthrax, yaws, malaria, trypanosomiasis, onchocerciasis, and filariasis. Wetland-associated biting flies may fly or be carried by wind or vehicles great distances from wetland or waterside habitats (up to 100 km or more) (King et al. 1960:42, 74; Fredeen 1987; Lehane 1991:221).

Warmth, warm air, moisture, sound, movement, size, light intensity, pattern, shape orientation, form, contrast, color, carbon dioxide, lactic acid, acetone, butanone, octenol, and phenolics attract biting flies to hosts (Gillett 1972:107, Fears 1979:125, Bowen 1991, Lehane 1991:30-49). Attraction of mosquitoes to humans varies with age, sex, perspiration, and skin health (Maibach et al. 1966, Brody 1983:413, Lehane 1991:18). Different fly taxa may preferentially bite different human body parts (Metcalf et al. 1962:943, 1005; Lanham 1964:224; Gillett 1972:110-111; Borrer et al. 1989:549; Lehane 1991:223).

Onchocerciasis, a filarial disease transmitted by black flies, affects 20-40 million people in Africa and South America (Kim and Merritt 1987:xiii, World Health Organization cited in Lehane 1991:3, 212). The WHO (*ibid.*) estimated that 220-365 million people were infected with malaria, 90-250 million with mosquito-borne lymphatic filariasis, and >20,000 with tsetse-borne African sleeping sickness (trypanosomiasis). At the beginning of World War II an estimated one-third of the world population had malaria (Klayman 1989). In the 1800s and early 1900s, malaria mortality occurred nearly throughout the U.S. (Matheson 1966:53), but by 1930 indigenous malaria was limited to the Southeast, and cases became scarce during the 1950s (King et al. 1960:18). Indigenous malaria was eradicated from the last several European countries as recently as the 1960s and early 1970s (Bruce-Chwatt and de Zulueta 1980:7-8). Malaria is said to have contributed to the fall of ancient Greece and the Roman Empire (Gillett 1972:244-245, Bruce-Chwatt and de Zulueta 1980:2). Cultural traditions that developed in response to a threat of the magnitude of malaria are not all likely to be extinguished in the 1-2 human generations since indigenous malaria vanished from Europe and the U.S.

Apart from transmitting pathogens and parasites, abundant mosquitoes and black flies can cause serious illness or death to unprotected persons (Fears 1979:125; Borrer et al. 1989:545; Lehane 1991:218). Lower levels of biting cause misery and reduce the efficiency of labor (Anon.

1939:3, 20; Anon. 1971:7-1; King et al. 1960:23; Matheson 1966:48). Sand flies, black flies, biting midges, mosquitoes, and stable flies influence real estate development and tourist economies in many regions (Hansens 1951), and fly-borne diseases such as malaria and onchocerciasis can retard indigenous economic development (Lehane 1991:5, 218-219). Malaria and certain other biting-fly-transmitted diseases are on the rise worldwide; malaria, dengue, and encephalitis could become major public health problems in the U.S. (Lederberg et al. 1992, Mitchell et al. 1992). Horse flies are suspected of transmitting Lyme disease in the U.S., although ticks are the principal vectors (Foil 1989). In order to avoid increased use of insecticides and the hydrologic and vegetational alteration of wetlands, low-impact programs of integrated pest management must be developed and implemented.

How do people lacking modern pesticides, repellents, and screens protect themselves from biting flies? Because of the high potential rates of morbidity and mortality associated with fly bites, any tactic of protection which reduces fly bites might confer a cultural or reproductive advantage. The diversity and adaptability of the flies, and the threat of their bites, means that people will continually invent and test new tactics of protection and that successful tactics are likely to be transmitted within and between cultures whether or not the users of those tactics are conscious of their function in reducing fly bites.

A culture trait which confers protection against biting flies may also serve other functions, of which fly protection may not be primary. The same trait may have different functions outside wetlands or in other cultures or regions. A trait which serves one or more functions in addition to protection against flies might persist better between periodic or aperiodic fly problems. Even some tactics with very little utility against fly bites could persist as part of a repertoire that helps people cope psychologically with the frightening and confusing phenomena of flies and fly-borne diseases. Tactics of protection may be conscious or unconscious responses to the flies themselves or to fly-borne diseases, whether or not the fly-disease connection is consciously understood. Some widely-separated traditional and rural cultures associated human and livestock diseases with arthropod vectors before modern science demonstrated these specific relationships (Lehane 1991:1-2).

In this paper I survey and classify human responses to biting flies, and comment on cultural and environmental implications of this information. Early in this study, I considered the types of behavioral and technological resources potentially available in small-scale cultures to cope with large numbers of biting flies, and I hypothesized that certain culture traits with no obvious connection to flies might conceal fly protection tactics. This reasoning led me, for example, to the relationships between incense and smudge, cosmetics and repellents, sleeping nets and bed curtains, all of which have been commented on by other authors. My emphasis is on traditional culture traits, but I draw on modern practices for interpretation of recorded or hypothesized traditional tactics, and *vice versa*. Many information sources lack detail, thus elements of my survey are indicative rather than definitive.

By "biting fly" I mean any species of Diptera which sucks blood from vertebrate hosts, although some writers (e.g. Lehane 1991) restrict this usage to the bloodsucking Muscidae. Scientific names of plants follow Bailey et al. (1976) or are taken from the literature cited herein.

## HUMAN RESPONSES TO BITING FLIES

### Avoidance

As illustrated for one wetland complex in the eastern U.S. (Table 1), the hazard of biting flies depends on taxon-specific behavior, habitat, environmental conditions, and human behavior, also alluded to by Errington (1957:104-105) and Weller (1987:47). Human-fly contact is reduced by locating shelters and work stations in the open, away from dense vegetation, above the ground, on breezy eminences, on or downwind of open water, upwind of wetlands, or away from habitats of particular species.

## **MIGRATION**

*Diel Migration.* Malaria mosquitoes (*Anopheles*) bite mostly at night, and people have commonly stayed indoors at twilight and night to avoid *Anopheles*, other mosquitoes, and biting midges (Herrick 1926:101, Jamnback 1969:53, Worth 1971:199). Anon. (1991) suggested that government agencies discourage outdoor public events in the evenings in areas of higher eastern equine encephalitis (EEE) transmission by mosquitoes in New York. Conversely, persons involved in illegal nighttime activities may have increased exposure to malaria (Oaks et al. 1991:262). Unlike *Anopheles*, black flies, horse flies, and stable flies bite in daytime even in open areas (Jamnback 1969:53). In summer, Tungus (Siberia) traveled at night to avoid flies (Shirokogoroff 1929:95).

*Seasonal Migration.* Numbers of active adult flies and their host selection (Lehane 1991:16) are strongly seasonal. Periods of abundance are typically of short duration, June-July for many species in New York (Jamnback 1969:53); he suggested avoiding forests of northern New York in late spring and early summer when snow-pool breeding *Aedes* mosquitoes are abundant. Pastoral cultures have commonly moved with their livestock seasonally to areas of lesser fly hazard, e.g. in Sardinia (Brown 1986). Georgia (U.S.) plantation-owning families moved from island homes to mainland, mountain, or city homes in summer to avoid mosquitoes and malaria (Teal and Teal 1964:63-64, Dubisch 1985).

## **SITE**

Madan (Tigris-Euphrates delta) built shelters in open pools rather than in beds of tall, dense reeds (*Phragmites*) (Maxwell 1957:60). In summer, Western Woods Cree built lodges on lakeshore or riverbank exposed to winds that inhibited fly activity (Honigmann 1981:262). Nuer (Sudan) built flood-season villages on elevated ridges in part to avoid mosquitoes (Evans-Pritchard 1940:63-64). Native South Africans avoided camping near fever trees (*Acacia xanthophloea*) which indicated wet soil and malaria hazard (Worth 1971:49, 199).

As a component of malaria control, Phillips (1983:55) recommended locating houses away from mosquito-frequented areas. Jamnback (1969:53) urged that homes and camps be situated in "open, sunny, windswept spots" rather than dense woods. Housing should be upwind of the nearest water and 0.8-1.6 km from possible anopheline larval habitats because pumping domestic water to houses is cheaper than malaria control (Bruce-Chwatt 1985:269).

## **ARCHITECTURAL**

Biting flies tend to stay near vegetation. Most mosquitoes fly within 9 m of the ground, sand flies within 3 m (Craighead and Craighead 1956:190, 193). In the southern U.S., people slept on the second floor of a house to reduce exposure to malaria (Storer 1926). Pile houses are widespread, and avoidance of biting flies appears to be an important function of elevated architecture.

## **SUBSTITUTION**

Early-1800s plantation agriculture in the southeastern U.S. depended on the labor of African-American slaves who, due to sickle cell trait, were more resistant to malaria than whites (Teal and Teal 1964:65-66, Dubisch 1985).

## **NON-USE**

Ephemeral non-use, e.g. selection of a breezy eminence for an eating or resting place, is very common. Biting flies have also kept people out of certain wetland and shore habitats permanently or nearly so, thus protecting natural areas from overuse and alteration. Ayres (1990) described a section of the Amazon which, in spite of plentiful fish, was uninhabited probably because of "enormous swarms of mosquitoes present in all seasons and at all hours of the day" and tremendous fluctuation in water level. Areas of Amazonia have been avoided by humans because of malaria, and areas of West Africa because of onchocerciasis (Curtis 1990:195). Cape Sable, Florida, U.S. (Carr 1973:161-162) and the Okavango Swamp, Botswana (Cowley 1968) have

been largely unused because of biting flies. Tsetse flies and *nagana* (a tsetse-borne livestock disease) in subsaharan Africa prevented invasion by mounted armies, limited use of draft and pack animals, and obviated ungulate ranching in perhaps 10 million km<sup>2</sup> (Glasgow 1961; Lehane 1991:21, 233); it has been argued that tsetse also limited development, prevented overgrazing and desertification, and protected wild game in vast areas (Lehane 1991:21, 233).

Residential, resort, and industrial development has been retarded and property values less in districts with abundant mosquitoes, and successful mosquito control has increased development and enhanced property values in some regions (King et al. 1960:23; Matheson 1966:48, 58-59). Vacationers may avoid certain districts of Scotland (Colyer 1951) because of the abundance of biting midges.

## **Barrier**

Barriers block access of biting flies to the skin, at various distances from the human body.

## **CLOTHING**

A scarf covering ears and neck has been used for fly protection (Jaeger 1945:179). Phillip Barske (West Falmouth, Massachusetts, U.S., pers. comm.), as a child in southern New England, was told to wear a scarf outdoors, which he interprets as an anti-malaria measure.

A thick, loosely woven tunic in wide use in aboriginal Amazonia protected against insects (Lathrap 1970:119). A similar tunic worn by Madan men was wrapped about the legs for protection when sitting in boats, but could be hiked up or slipped off readily for wading or swimming (Maxwell 1957:137, Thesiger 1964:160). The historic Seminole (southern Florida) male costume was a long, complex dress which protected against insects and was tucked up when wading (Densmore 1956, Sturtevant 1967). The Roman toga may have been designed to be wrapped around the body for protection against mosquitoes (Kirkland 1969:106).

The adoption of western clothing by acculturating peoples has significance for insect protection. Mundurucu (Brazil), much bothered by biting flies, lived on the breezy savanna rather than in the resource-rich riparian zone, and eagerly gave up nakedness for trade clothing (Murphy and Steward 1956). Barbara Nowak (pers. comm.) found the Btsisi (Peninsular Malaysia) valued long-sleeved shirts and long pants for protection against insects in the mangroves. Covell (1931:3, 5) urged that military personnel in India wear long pants, long sleeves, and gloves at night to prevent malaria.

Ryden (1941:39) interpreted the habit of naked Siriono (Bolivia) men of tucking the penis between the scrotum and thigh as insect protection, and suggested the same function for the penis-sheath that is common among tropical forest cultures in South America. Considering the potential sensitivity of the highly-vascularized external genitalia to irritation by insects and plants, I am not surprised that many cultures cover the genitalia before anything else.

Headwear can play a vital role in protecting a large, highly vascularized, warm, and easily-irritated part of the body from bites, and reducing the annoyance of insects buzzing near the ears and entering ears, eyes, nose, and mouth. Footwear may be important because biting flies often rest near the ground during the day, and because stable flies and some mosquitoes attack the ankles and feet. Fears (1979:28-29) recommended high boots to protect feet and ankles from insects and mechanical injury, and Covell (1931:3) and Bruce-Chwatt (1985:267) referred to "mosquito boots" of leather, canvas, or rubber. An alternative is to tuck the pants legs into heavy socks (Bruce-Chwatt 1985:267). Black flies tend to crawl inside clothing before biting (Jamnback 1969:54); therefore clothing must be sealed, e.g. by tucking pants into socks, or repellents must be applied to openings.

## **HEAD NETS**

Head nets are principally worn by active people outdoors in northern environments, to protect the wearer from day-biting mosquitoes and black flies (Gillett 1972:12); head nets are also used in warm climates (Fears 1979:30). Kalm (1770:337) mentioned "caps which cover the

whole face, [or] gauze over the eyes." Covell (1931:3) reported veils worn at night by male guards in India.

Bruce-Chwatt and de Zulueta (1980:plate 23) illustrated a 1920s European head net with a port for a tobacco pipe! Head nets interfere with vision, drinking, and eating, and catch on vegetation (Jamnback 1969:54). Head nets may be treated with repellents for greater effectiveness (Bruce-Chwatt 1985:268).

### ***SHELTER***

Screening for windows, doors, and porches constitutes one of the cheapest, safest, and most effective forms of protection. Other routes of entry may need sealing. Kalm (1770:77) said of the northeastern U.S., "The chimneys of the English, which have no dampers for shutting them up, afford the [mosquitoes] a free entrance into the houses." Subsequent adoption of dampers in the northeastern U.S. might have been useful to adjust indoor smudge as well as preventing the influx of insects when the fires were out. Covell (1931:6) noted controversy about the efficacy of suspending naphthalene in chimneys to discourage mosquito entry. Anonymous (1939:30) recommended use of tongue-and-groove boards to prevent ingress of *Anopheles* through house floors.

The Kimam (Irian Jaya, Indonesia) had wall-less daytime shelters, and special sleeping huts which were tightly thatched with grass and contained smudge fires (Serpenti 1965:6-8, 12). Contrary to tight architecture, some tropical peoples (e.g. Yaruro of the Orinoco Llanos, Venezuela [Petrullo 1939]) built houses with open walls which allowed the wind to discourage biting flies from settling.

### ***SKIN***

Animal fat, mud, and other dense or viscous (and sometimes toxic) substances have been applied to the skin as a fly barrier. Dinka (Sudan) used cow dung ash (Seligman and Seligman 1932:137). Warao (Venezuela) smeared mud on themselves before crabbing in the mangroves (Wilbert 1972:83). Kalm (1770:336-337) said people of northern New York smeared butter or grease on their faces, and wrapped paper around their legs under their stockings. Cosmetics used by the ancient Egyptians protected the eyes from insects as well as from glare and dust according to Montet (1958:69-70).

### ***SLEEPING NETS***

Among peoples of the middle Sepik River, Papua New Guinea, mosquito bags of finely woven sago palm (*Metroxylon rumphii*) materials were a necessity and an important item of commerce (Gewertz 1983:91). Woven mosquito bars were evidently indigenous in Amazonia (Lathrap 1970:88, 119). Bed nets have been in widespread use for centuries and possibly millenia (Covell 1931, King et al. 1960:33, Matheson 1966:77, Bruce-Chwatt 1985:266-267). Panati (1987:327) suggested the original function of bed drapes and canopies was for protection against mosquitoes; the English word "canopy" is derived from the Greek for mosquito net (Partridge 1958).

### **Control**

Control constitutes killing flies or interfering with their reproduction, rather than just preventing biting.

### ***BIOLOGICAL CONTROL***

Biological control includes manipulation of pathogens, parasites, predators, competitors, alternate hosts, and other symbionts of target organisms. Modern practical and experimental bio-control of mosquitoes, black flies, and the horn fly uses fungi, bacteria, protozoa, nematodes, crustacea, insect predators and competitors including other mosquitoes, fishes, frogs, birds, and mammals. It is not clear to what extent these modern control techniques were presaged by traditional techniques.

The mosquitofish (Poeciliidae: *Gambusia affinis*) and probably more than 100 other fishes (Cyprinidae, Cyprinodontidae, Fundulidae, Poeciliidae, etc.) have been used to prey on mosquito larvae in temperate and tropical regions worldwide, some traditionally (International Health Board 1924).

Lewis (1942) reported that juvenile turtles ("*Pelamedusa galeata* Schoepff" = *Pelomedusa subrufa*, the helmeted turtle?) were kept in water storage jars of the Moro (Sudan) to eat larvae of the mosquito *Aedes aegypti*, a vector of yellow fever. Domestic chickens and pigs have been kept with cattle to eat horn fly larvae in cow dung (Metcalf et al. 1962:956).

Thompson (nd) stated that nest boxes were erected at cranberry bogs in southern New Jersey, U.S., to attract purple martins (*Progne subis*) for controlling mosquitoes. Kale (1968), however, argued that martins were unlikely to control mosquitoes because of the ratio of martins to mosquitoes and the lack of temporal and spatial overlap in activity. Hill (1992) suggested martins might have a local effect, controlling nuisance insects near martin nest colonies. Hill (1992) and Allen and Nice (1952:615) speculated on other reasons for Native American and European-American erection of nest structures for purple martins, including repulsion of other birds that damaged crops, hides, and meat.

Although some bats (Chiroptera) feed heavily on mosquitoes, there has been controversy over the efficacy of natural bat populations, or populations enhanced by erection of roost structures, in controlling mosquito populations (Campbell 1925, Storer 1926, Tuttle 1988:39-40). Fargo (1929) suggested the absence of mosquitoes on a mangrove island in southern Florida might have been due to ammonia from the guano of bats roosting in the trees.

In the early and middle 1900s in the Zambezi River valley, Africa, unsuccessful attempts were made to control tsetse flies, first by shooting all large wild vertebrate hosts, then by creating a fenced, 16 km wide, game-free zone along the valley edge (Teede and Teede 1990:56-57).

#### **CHEMICAL CONTROL**

Traditional botanical preparations have been used as mosquito larvicides, e.g. neem (*Azadirachta indica*) and garlic (*Allium sativum*) (Amonkar and Banerji 1971, Olkowski et al. 1991).

#### **PHYSICAL CONTROL**

*Raking.* A stable broom or iron rake (with or without a stationary cheesecloth net) has been used in the U.S. to loosen black fly larvae from the rocks in critical segments of stream bed (Conradi 1905).

*Swatting and Brushing.* Swatters or fly-whisks have been used for protection from tsetse flies outdoors (Schweitzer 1951:127, 1961:29) and from mosquitoes indoors (Covell 1931:11).

#### **Distraction**

#### **BROAD-BRIMMED HATS**

Broad-brimmed hats have been widely used by American outdoorspeople, e.g. in Maine. Jamnback (1969:54) noted that deer flies (Tabanidae: *Chrysops*) often linger on a hat brim instead of biting the wearer.

#### **DEVIATION**

In northern Europe, the mosquito *Anopheles maculipennis* was more attracted to livestock than to humans and the stabling of livestock next to houses reduced biting of humans (Bates 1949:24). In southern Europe, pigs in sleeping rooms attracted *Anopheles* away from humans (Gillett 1972:106). In Italy after World War II, reduced numbers of livestock caused zoophilous mosquitoes to feed on humans (Phillips 1983:54). Lehane (1991:20) summarized changes in human and livestock demography in Europe which led to deviation of *Anopheles* from humans to animals. "Zooprophylaxis" or locating cattle, water buffalo, or horses between mosquito sources and houses, has helped reduce malaria in China, the former Soviet Union, Vietnam, the U.S., and elsewhere (Rambo 1973, Bruce-Chwatt 1985:294-295, Oaks et al. 1991:228). Kalm (1770:77,

also see 141), nonetheless, noted that in the northeastern U.S., "On sultry evenings [mosquitoes] accompany the cattle in great swarms from the woods to the houses or to town, and when they are driven before the houses, the [mosquitoes] fly in wherever they can." Dubisch (1985) speculated that overharvest of white-tailed deer (*Odocoileus virginianus*) in South Carolina might have caused zoophilous *Anopheles* to bite humans more.

### **FLAGS**

In the Fenland of East Anglia, U.K., flags of light-colored cloth were used to distract mosquitoes from humans (Darwin David Horn, Los Angeles County Museum, California, pers. comm.).

### **WARM WATER**

In Uganda, Gillett (1972:105-106), after noticing that the mosquito *Coquilletidia fusco-pennata* was attracted to his shaving bowl, regularly used a pot of warm water to distract mosquitoes from himself.

### **Fanning**

Hand-fans have been used by Dinka (Sudan), Warao (Venezuela), and elsewhere to prevent flies from landing or to flick or blow them off the body (Covell 1931:3, Kirchoff 1948:873, Deng 1974:3).

### **Habitat Management**

Kalm (1770:398) said of Canada, "...when the forest is cut down, the water drained, and the country cultivated, the ["gnats" = mosquitoes?] probably will decrease in number and vanish at last, as they have done in other places." The complexity of the niche of mosquitoes (two habitats, aquatic and terrestrial, and three foods, detritus, nectar, and blood) and some other taxa suggests possibilities for control by eliminating critically required elements.

### **ARCHITECTURAL HABITAT MANAGEMENT**

Well-lit and well-ventilated houses discourage indoor resting by mosquitoes and other biting flies (Curtis 1990:200). Lehane (1991:20) noted that the trend to larger, better lit houses in Europe was a factor in shifting of *Anopheles* from humans to livestock.

### **CLIMATE MANAGEMENT**

Herrick (1926:101) recommended that sleeping rooms in the southeastern U.S. be allowed to cool at night in autumn to reduce mosquito activity.

### **HYDROLOGICAL MANAGEMENT**

From the early 1600s, wetland drainage was used for malaria control in Italy (Phillips 1983:3). Widespread drainage for combined malaria control and agricultural conversion was practiced in the U.S. (King et al. 1960:28). Modern methods of water and wetland alteration for biting fly control include stream channelization, drainage and ditching of wetlands and pools to remove water or to allow entry of aquatic predators, intermittent drying of ponds and pools, filling wetlands, impounding streams, flushing streams by temporarily increasing flows, excluding tidal waters with dikes, impounding incoming tidal waters to increase salinity, and eliminating artificial and natural container habitats such as discarded automobile tires, treeholes, and bromeliad tanks. As differences between wetland alteration in traditional and modern cultures are quantitative rather than qualitative (Kiviat 1991:96-97), it would be interesting to know to what extent modern methods of hydrological management for biting fly reduction had traditional precedents. Raised field cultivation (alteration of wetlands to create cultivation ridges separated by channels) was widespread. In deeper wetlands, the channels would have had an effect similar to that of mosquito ditches in tidal marshes, eliminating isolated pools and enabling fish to prey on mosquito larvae. Besides ditching, most hydrological management has involved making habitats un-

suitable *per se* for fly larvae rather than enhancing populations of control organisms or their access to flies.

### **VEGETATION MANAGEMENT**

*Management of Terrestrial Vegetation.* Recommendations issued by the U.S. Surgeon General in 1906 (Herrick 1926:104-107) included the clearing of "weeds, grass, and bushes about ditches, ponds, and other possible breeding places, since these afford a hiding place for the mosquitoes." Matheson (1966:66-67) recommended clearing the banks and adjoining areas around reservoirs, ponds, and streams; Penfound (1953) also mentioned clearing woody and herbaceous vegetation. Clearing scrub generally eliminates resting habitats for adult mosquitoes, dries up small pools, and reveals hidden larval habitats (Bruce-Chwatt 1985:288). Livestock grazing has been used to manage vegetation on reservoir banks for malaria control (Hess and Hall 1945:39). Complete clearing of woody vegetation has been used to control tsetse fly in Africa, but the clearing must be extensive to be effective (Glasgow 1961). Anonymous (1971:7-17) recommended close mowing, thinning of woody plants, and maintaining space between plants and house walls to reduce cover for biting midges.

Contrary to clearing of riparian vegetation is the planting of *Duranta* and other shrubs which produce dense shade on stream banks, eliminate stream margin aquatic plants, increase current speed along the banks, and deter breeding of certain sun-requiring *Anopheles* in India (Bruce-Chwatt 1985:287). Hopkins (1940) recommended mango (presumably *Mangifera indica*) and fig (*Ficus* spp.) for shading drainage ditches in Uganda.

Clearing for cultivation often increases populations of certain *Anopheles* species which lay eggs in brightly sunlit water (Bruce-Chwatt 1985:288), and reforestation can be used to reduce *Anopheles* breeding (Oaks et al. 1991:228). Vegetation removal around houses, however, was recommended by Covell (1931:27) in India, presumably to remove resting shelter for adult mosquitoes. Cutting to let sun and wind through the forest canopy decreases humidity and increases light, disfavoring mosquitoes and biting midges in New York (Jamnback 1969:53).

Oaks et al. (1991:228) referred to "band deforestation" to control malaria. Deforestation or herbicides eliminated bromeliad phytotelmata and controlled malaria (Williams 1987:162). Russell (1941) mentioned vegetational barriers to block the flight of *Anopheles* mosquitoes; the results were inconclusive.

*Fire.* In any one environment-culture complex, the functions attributed to prescribed fire vary. Fire is supposed to control a variety of pests including bloodsucking arthropods, ticks (Jamnback 1969:55, Komarek 1972:133, 180, 362), insect pests of crops (Pyne 1982:146), and snakes (Shea 1940). In rural southern Florida in 1973 I heard this claimed about mosquitoes, ticks, and snakes. European-American hunters and fishers set "smudge fires" to "drive off" black flies and mosquitoes, reportedly after the manner of Native Americans (Pyne 1982:54, 60). Shea (1940) quoted a rural man of the southern U.S., "[Fire] keeps us healthy by killin' fever germs," presumably referring to malaria.

*Management of Aquatic Vegetation.* General removal of floating vegetation increases wind disturbance of the water surface and reduces mosquito oviposition (Matheson 1966:66). Removal of floating, trailing, and emergent aquatic vegetation has been recommended widely for control of *Anopheles* and other mosquitoes (King et al. 1960:29, 40-41). Two fishes, common carp (*Cyprinus carpio*) and *Tilapia*, have been used to reduce floating algae and rooted aquatic vegetation to improve larvicidal operations for mosquito control (Bruce-Chwatt 1985:292).

Some lemniid plants can rapidly reproduce vegetatively and cover water surfaces. Mosquitofern (*Azolla*), where sufficiently abundant on rice paddies (e.g. >80% cover) in India and China, inhibited both oviposition and adult emergence of mosquitoes (Rajendran and Reuben 1991). The duckweeds *Lemna* and *Wolffia* can have a similar effect on mosquitoes (Matheson 1930, 1966:75; Angerilli and Beirne 1982; Bruce-Chwatt 1985:289). Dense mats of common duckweed (*L. minor*) may create an anaerobic zone in the water column in which mosquito larvae

cannot survive because they cannot penetrate the duckweed cover to obtain oxygen from the air (Reed 1988:154). Lemnids reduce mosquito reproduction only where a nearly continuous cover is maintained, but mosquito larvae may be abundant where lemnid growth is scattered (King et al. 1960:33).

The macrophytic alga *Chara* and vascular plants including *Elodea* and *Brasenia* have been reported to interfere with mosquito oviposition and larval development, to release substances toxic to mosquitoes, or to provide favorable microhabitats for predators of mosquito larvae; taxonomic and ecological differences seem to have created confusion, however (Matheson 1930, King et al. 1960:33, Angerilli and Beirne 1982, Bruce-Chwatt 1985:289). Although it has been suggested that bladderworts (*Utricularia*), which capture and digest small invertebrates including mosquito larvae, can control mosquitoes, Bruce-Chwatt (1985:289) did not recommend plants for biological control. Some mosquitoes depend largely or entirely on certain plant species, for example two *Mansonia* spp. on water-lettuce (*Pistia*) (Matheson 1966, Gangstad and Cardarelli 1990). Reduction or elimination of the host plant can potentially reduce the mosquito populations.

Attempts have been made to control malaria by increasing evapotranspiration of water from wetlands with plantings of canna (*Canna*), senna (*Cassia*), castor bean (*Ricinus communis*), beefwood (*Casuarina*), chrysanthemum (*Chrysanthemum*), eucalyptus (*Eucalyptus*), neem, pine (*Pinus*), or sunflower (*Helianthus*) (Covell 1931:28, Russell 1941, Bruce-Chwatt 1985:288). Planting *Eucalyptus robusta* in Uganda graminoid marshes had some success (Hopkins 1940).

#### **WASTE MANAGEMENT**

Hansens (1951) and Jamnback (1969:55) noted that moist rotting detritus, such as livestock manure, lawn wastes, and seaweed windrows, can be made unsuitable as stable fly larval habitat by removal and burial, or spreading to dry.

Unintentional organic pollution and siltation from homes and farms can eliminate black flies from streams (Jamnback 1969:55) and make standing water unsuitable for *Anopheles* larvae (Oaks et al. 1991:263). Intentional pollution of pools or ponds with decomposing plant matter such as garden and yard wastes in Malaysia and India deterred egg-laying and killed larvae and pupae of some *Anopheles* species, but could produce a suitable habitat for other anopheline and culicine mosquitoes (Bruce-Chwatt 1985:289). Pollution can also reduce populations of mosquito-controlling native fishes (Olkowski 1987).

#### **Non-attraction**

Non-attraction is accomplished through reduction of the chemical and physical stimuli which attract biting flies to human skin.

#### **BATHING**

Frequent bathing supposedly reduces attractiveness to mosquitoes in the U.S. (Brody 1983:413) as it did to "gnats" (taxon?) among the Sharanahua in Peruvian Amazonia (Siskind 1973:73). Staying cool has also been recommended (Brody 1983:413).

#### **CLOTHING**

Fears (1979:125) stated that mosquitoes were more attracted to "shiny fabrics and pale colors" than to "dull-surfaced dark clothing," and noted that camouflage clothing was helpful. Fears (1979:30) also recommended staying dry because mosquitoes and tabanids were attracted to "warm, wet objects." Brody (1983:413, 415) stated that biting flies were attracted to dark colors rather than "light, dull colors." Schweitzer (1961:29) noted that tsetse flies avoided settling on light backgrounds (such as white clothes) where the flies would be conspicuous. Biting flies of five families were attracted least to orange and yellow, and most to blue, purple, and black; they were also attracted less to colors of higher intensity (value) and higher chroma (decreasing dullness) (Gjullin 1947, Hansens 1951, Davies 1961, Lehane 1991:42). Jamnback (1969:54) suggested bright fluorescent orange would be the best deterrent.

## **DIET**

Eating garlic (*Allium sativum*) or wild leek (*A. tricoccum*) is said to make the skin distasteful to mosquitoes or black flies, respectively (Fears 1979:126, Turco 1990:16). Taking vitamin B<sub>1</sub> (thiamin) is said to make one "smell unattractive to insects" (League of Women Voters 1990).

## **Repellents**

Metcalf et al. (1962:389) listed, in order of importance, the criteria of a good repellent: a. Effective, long-lasting protection of all persons under all conditions; b. No toxicity or irritation when used regularly; c. No harm to clothing and no unpleasant odor, taste, or feel; d. Protection against a wide variety of pests; and e. Ready availability and low cost. Botanical repellents such as eucalyptus or citronella may be effective but short-lived on the skin (Bruce-Chwatt 1985:268). Some substances are evidently repellent in low concentrations and insecticidal in high concentrations.

Altschul (1973) compiled food and drug use annotations from herbarium collections of 5178 plant species among which only 3 were burned as smudges, 1 was used as an indoor repellent, and 1 apparently as a personal repellent. It is not clear whether plant collectors are less likely to elicit informant comments on protection against flies, or if relatively few plants are thus used.

## **OUTDOOR**

Outdoor plantings to repel biting flies were noted by Russell (1941). Eucalyptus (*Eucalyptus*) (Tenney 1983:59), chinaberry (*Melia azedarach*), and castor bean have been noted as outdoor plantings to repel mosquitoes, but Herrick (1926:102-104) argued these were ineffective.

## **INDOOR**

Herbs have been used in and around houses in Europe and the U.S. to repel insects including biting flies ((Tenney 1983:59, Mabey et al. 1988:160). The marigold *Tagetes caracasana* was used as an insect repellent in houses in Colombia (Altschul 1973). Holy basil (*Ocimum suave*) is being used experimentally in Ethiopia as an indoor repellent (Grossman 1992). Creosote oil (probably a wood-tar or coal-tar fraction) has been applied to house walls and ceilings in the U.S. and Italy, to repel mosquitoes, with mixed results (Covell 1931:4-5).

## **PERSONAL**

Topical repellents may be distasteful or toxic to insects or may mask the attractant odors of the body. Many herbal products have been used topically as insect repellents; some are listed in Table 2. Repellents are often used in mixtures, and it is not always clear which plants are efficacious. Some modern commercial repellents combine synthetic and herbal ingredients. That camphor (Table 2) was often used in early 1900s U.S. repellent mixtures could be due partly to a local anesthetic effect (Holmes 1990) on bites of flies that were not repelled. Kephart (1921:246) said that protection afforded by a given repellent compound varies according to the numbers, taxa, and behavior of the flies, and the individual person; thus, popular repellent preparations were mixtures of ingredients.

Mineral substances were also used as repellents and possibly barriers. Malachite and galena (copper and lead compounds, respectively) were used to protect eyes from effects of glare, dust, wind, and insects (Montet 1958:69-70). Sulfur and potassium sulfate have been used to repel biting flies (Kephart 1921:247, Covell 1931:4, Worth 1972:10) as well as to repel or kill mites.

## **Smudge**

The use of smoke to repel, stun, or kill biting flies is one of the most widespread protection tactics. Smudge fuel may be ordinary household or outdoor fuel or may be enhanced by the addition of wet materials (e.g. green wood, wet rotting wood, wet dead leaves, green leaves, moss, lichen, or dung [Seligman and Seligman 1932:137, Angier 1974:289]). Smudges may also be specifically toxic, e.g. citronella (see Table 2), orange peel (*Citrus*), pyrethrum (*Chrysanthemum cinerariifolium*, *C. coccineum*), tobacco (*Nicotiana*), or jimsonweed (*Datura stramonium*) (Covell 1931:18-19, 23, 109; Fears 1979:46, 91). Altschul listed three species burned as smudges against mosquitoes: *Croton watsonii* (Euphorbiaceae) and *Tagetes lucida* (Asteraceae) in Mexico, and *Strumpfia maritima* (Rubiaceae) in the Bahamas. Sulfur has been burned to kill mosquitoes (Covell 1931:20).

## **INDOOR**

Many cultures built nighttime or all-purpose shelters without flues, e.g. Ila of the Kafue Flats, Zambia (Smith and Dale 1920:I:121) and Irish (Evans 1957:45, 59). People sat or slept on stools or beds or in hammocks over smoky fires (Bateson 1932:259, Suarez 1968:28, Newton 1971:14, Wilbert 1972:80), and smudge fires were even maintained in canoes (Gewertz 1983:18).

Pyrethrum products have been burned indoors to kill mosquitoes for centuries, a practice which was culturally intertwined with the use of joss-sticks (incense) (Covell 1931:3, Casida 1973:228, Bruce-Chwatt 1985:268). Myrrh (*Commiphora erythraea* resin) incense was burned to repel mosquitoes (Grossman 1992). What substances other than pyrethrum and myrrh were burned in incense form to prevent insect bites, and whether smudge or the ritual and odorant functions of incense came first, await historical clarification.

## **OUTDOOR**

Smudge fires have been used in house yards or sporting camps in New York and elsewhere to repel biting flies (Jamnback 1969:54, Casida 1973:228).

## **PERSONAL**

Colyer (1951) noted that smoking tobacco helped protect the smoker from black flies. American fishers and other outdoorspeople have used this tactic widely.

## **DISCUSSION**

Biting flies, and the wetlands which produce them, have greatly influenced human culture. The influences of wetlands extend beyond their boundaries because of fly dispersal and human movements in and out of wetlands. There is a multitude of human responses to biting flies, many of them intense, variable, or pervasive; they intermesh in complex ways with other elements of material and non-material culture. The occurrence of similar tactics of fly protection in widely dispersed geographic regions and despite the disjunct nature of wetlands, indicates adaptation of culture to biting flies and to wetland habitats (Kiviat [1991] noted this for other cultural adaptations to wetlands).

Typically, protection tactics are combined for effectiveness. Peasants of the Tonkin delta (Vietnam) cultivated their lands cleanly thus reducing the larval habitat available to *Anopheles*, and avoided the surrounding malarious hill country; if they worked on farms at the delta margin they returned to delta villages at night (Gourou 1961:100). The hill people in Vietnam built pile houses to raise their beds above the mosquito activity zone, stabled livestock beneath the floors to deviate mosquitoes, and used smudge fires (Rambo 1973). Amazonian natives had tight houses with smudge fires, woven mosquito bars, and thick garments; the last two permitted a shift to otherwise more healthful, open houses (Lathrap 1970:88, 119).

Tight shelters, repellents, and house siting, for example, are prominent in both modern and traditional repertoires. Screens block flies while permitting ventilation and vision, thus are technologically more advanced than mosquito bags. Siting of houses often still emphasizes or creates low vegetation stature and greater air movement. Strategies for protection appear similar, and tactics quantitatively but mostly not qualitatively different, in the development of modern from traditional practices (see Hydrological Management, above). Many tactics tested by public health agencies in the U.S. in the 1900s may have been based on tactics used by rural and small-scale cultures. Even if these low-technology tactics were not in fact secondarily derived, they represent tactics which *could* have been used in a small-scale context, and may provide clues for studying fly-avoidance behavior in other cultural settings.

Some protective practices seem to have become culturally coded as high-status behaviors. For example, well-drained, broad, neatly trimmed lawns, house compounds lacking organic refuse, lakes and ponds without floating-leaved and emergent aquatic vegetation, and woods clear of undergrowth, are regarded in much of the U.S. and Europe as symbols of higher socioeconomic status. There may be a cultural mechanism encouraging emulation of behaviors which reduce the reproduction of flies and their attraction to humans. This mechanism could have derived from social and cultural communication illustrated by the following hypothetical examples: 1. Eye make-up may have signalled, "I am a healthy, attractive person because I am wearing paint which protects me from injury and disease"; 2. The tobacco pipe or cigarette may have signalled, "I am smart and powerful because I know how to smoke to keep the insects away."

Early in my survey, I hypothesized that many plant products with widespread use as cosmetics, indoor scents, or culinary spices would also serve to repel biting flies. There is supporting evidence for protection functions of annatto, sandalwood, eucalyptus, garlic, lavender, cloves, and others (Table 2); other materials bearing investigation include henna (*Lawsonia inermis*), saffron (*Crocus sativus*), calamus (*Acorus*), tansy (*Tanacetum vulgare*), and patchouli (*Pogostemon patchouli*) (the last two are "insect" repellents according to Lust [1974:566]). Fly protection should be considered in ethnographic and archeologic interpretation of such aspects of culture as: spatial and temporal activity patterns; fears of the dark, water, dense vegetation, or still air; bathing and shaving habits; clothing design, materials, and colors; headware including turbans, neckcloths, scarfs, and veils; footwear including socks; jewelry of botanical materials; configurations of streets, courtyards, vista clearings, and houses which facilitate air movement; insulation of houses, e.g. "chinking" of log houses; hearths, flues, drafts, fires, smudge, smoking, incense, candles, and torches; sudatories; flags, banners, and "wind socks"; cultivation techniques; diet, culinary herbs and spices, and dietary prescriptions and proscriptions; drying, storage, and disposal of organic materials such as fodder and crop residues; waste disposal in waterways; and the introduction of insectivorous or herbivorous fishes into natural or artificial waters. It would be informative to trace the frequency of potentially fly-related culture traits diachronically with changes in the abundance of e.g. *Anopheles* and malaria.

A clearer understanding of the relationship of culture and human behavior to protection against flies could help in public education and environmental management to reduce negative impacts of protection tactics. Potential areas of improvement include: hydrological alteration of wetlands, streams, and ponds; alteration and removal of aquatic and terrestrial vegetation; "culling" of dead, damaged, and misshapen trees in forestry; and the introduction of plants and animals. King et al. (1960:29) recognised that removal of woody vegetation from banks could cause

soil erosion and siltation and result in the creation of new larval mosquito habitats downstream; Glasgow (1961), however, found that clearing riparian woody vegetation in Africa for tsetse control resulted in greater stabilization of banks by grass.

Fly protection tactics often have other functions, which may save time and energy as well as optimizing and preserving the fly protection repertoire during periods of low fly hazard. Thus long, thick or tightly-woven clothes protect against sharp plants and cold as well as flies, and indoor fires are used for cooking, heating, lighting. Smoky fires inside dwellings preserve the shelter materials (e.g. thatch) against untimely decay in high humidity (Evans 1957:45, 59; Williams 1972:50). Cosmetics can protect the skin from ultraviolet light and desiccation. The mosquito bar provides warmth and privacy (Siskind 1973:192-193). Fly protection can also contravene other culture traits; tucking pants into boots or socks excludes flies and ticks, but reduces the value of loose trouser legs in deflecting snake bites.

Traditional protection tactics of small scale cultures and rural people can potentially be adapted as substitutes for: a) modern insecticides (e.g. DDT) and repellents (e.g. DEET and R-11) with undesirable health or ecological side-effects; b) environmentally destructive habitat management techniques (e.g. grid-ditching of tidal salt marshes); c) window screens and other fly-"tight" features (when natural disasters or economic disadvantage obviate modern conveniences). The New York State Department of Health (1992) warned of the potential toxicity of DEET and included recommendations for its use to reduce risk of adverse reactions, and the U.S. Environmental Protection Agency recently issued a warning about toxicity of R-11 to the reproductive system. Renewed study of repellents, smudges, and insecticides of herbal origins would be promising. Even if innovative high-technology tactics currently being developed, such as an anti-mosquito vaccine for humans and genetic modification of mosquitoes to make them incapable as vectors (Oaks et al. 1991:133), are successful, there will still be an important role for inexpensive techniques using readily available local materials and lacking major environmental impacts. The work of Green et al. (1991) with marigold (*Tagetes minuta*) oil as a mosquito larvicide is an example of a modern tactic suggested by tradition; they noted that because *T. minuta* has a wide geographic range, its oil can be extracted with steam, and it is probably effective against various mosquito genera, the plant could be a useful element in control strategies.

There is increasing concern about resurgence of fly-borne diseases. Many mosquitoes have become resistant to DDT or other synthetic insecticides (Phillips 1983:56, Bruce-Chwatt 1985:329, Oaks et al. 1991:132). Insecticide resistance is a factor in recent increases of malaria in many warm-temperate and tropical regions (Phillips 1983:57-58). In Europe, indigenous malaria could result from cases imported by returning tourists should there be a breakdown of health services due to war or other catastrophe (Bruce-Chwatt and de Zulueta 1980:177-179). In the U.S. there could be an increase in encephalitis, a return of dengue transmitted by the recently introduced tiger mosquito (*Aedes albopictus*), and a resurgence of indigenous malaria (Olkowski et al. 1991:663, Lederberg et al. 1992, Mitchell et al. 1992). The repertoire of environmentally-responsible fly management methods needs diversification and optimization for modern conditions. There has been little study of the epidemiological significance of low-technology protective tactics such as reported here (Dunn 1988); understanding the natural history of these tactics is the first step to evaluating their influence on disease transmission.

Fly hazards should be considered in planning residential development, instead of allowing homes to be built in areas of high fly hazard and necessitating future pesticide applications. Swatek (1970:72) recommended not building homes on low floodplains with abundant mosquitoes. Anonymous (1991) recommended stricter zoning regulations and warnings to potential buyers of homes near wetlands in areas of New York at high risk for EEE.

Knowledge of cultural adaptations to biting flies may elucidate human reactions to other arthropod vectors. Lyme disease is transmitted to humans by *Ixodes dammini* and other ticks in North America and Europe. Study of human responses to ticks in the Lyme disease foci of coastal Connecticut, New York, and New Jersey would offer an interesting comparison to the worldwide tactics of fly protection I have surveyed. The results could be useful in designing better programs of public education about both ticks and biting flies. Cultural adaptations to biting flies and fly-borne diseases might also serve as a model for understanding and enhancing cultural responses to diseases transmitted by other means, such as AIDS.

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TABLE 1. Collective tendencies in the spatial and temporal distribution of active, adult, biting flies (Culicidae, Tabanidae, Ceratopogonidae, Simuliidae) in the Tivoli Bays freshwater tidal wetlands, Hudson River, New York.

	<b>Distribution</b>						
<b>Fly abundance</b>	<b>Diel</b>	<b>Season</b>	<b>Vegetation</b>	<b>Edge</b>	<b>Wind</b>	<b>Hu- midity</b>	<b>Cloud</b>
<b>Abundant</b>	Night	Early	Woody	Edge	Calm	High	Cloudy
<b>Scarce</b>	Day	Late	Herbaceous	Interior	Windy	Low	Clear

TABLE 2. Examples of topical botanical repellents. Scientific names in brackets are inferred from common names given in the references cited.

Common name	Sci. name	Family	Locale (a)	References
?	<i>Chenopodium</i> sp.	Chenopodiaceae	U.S.: Arizona, New Mexico (Navajo) (d)	Elmore 1944:110
Anise (oil)	[ <i>Pimpinella anisum</i> ]	Ammiaceae	India (e)	Covell 1931:4
Annatto	<i>Bixa orellana</i>	Arecaceae	Bolivia (Siriono) (e)	Holmberg 1950:39-40
Basil	<i>Ocimum basilicum</i> , <i>O. suave</i>	Lamiaceae	East Africa (e)	Grossman 1992
Bergamot (oil)	[ <i>Citrus aurantium</i> ssp. <i>bergamia</i> ]	Rutaceae	India (e)	Covell 1931:4
Camomile	[? <i>Chamaemelum nobilis</i> , ? <i>Matricaria chamomilla</i> ]	Asteraceae	U.S.	Mabey et al. 1988:161
Camphor (oil or spirits)	[ <i>Cinnamomum camphora</i> ]	Lauraceae	India; U.S.: Northeast, etc. (e)	Kephart 1921:246, Covell 1931:4, Granett 1940, Matheson 1966:76
Castor (oil)	[ <i>Ricinus communis</i> ]	Euphorbiaceae	Canada; U.S.: Northeast, etc. (d,e,f)	Kephart 1921:246, Granett 1940, Jaeger 1945:179, Matheson 1966:76
Cedar, cedarleaf, cedarwood (oil)	[ <i>Juniperus</i> ]	Cupressaceae	India; U.S. (e)	Kephart 1921:246, Covell 1931:4, Granett 1940
Citronella (stone root)	<i>Collinsonia canadensis</i> (b)	Lamiaceae	U.S. (d)	Mabey et al. 1988:161
Citronella	[ <i>Cymbopogon nardus</i> ]	Poaceae	U.S. etc.	Kephart 1921:246, Matheson 1966:76, Bruce-Chwatt 1985:268
Cloves	[ <i>Syzygium aromaticum</i> ]	Myrtaceae	U.S. (d,e)	Kephart 1921:246, Covell 1931:4
Elder	[ <i>Sambucus</i> ]	Caprifoliaceae	U.S.	Mabey et al. 1988:161
Eucalyptus (oil)	[ <i>Eucalyptus</i> ]	Myrtaceae	India, U.S. (e)	Kephart 1921:246, Covell 1931:4, Matheson 1966:76, Bruce-Chwatt 1985:268
Garlic, onion, etc.	<i>Allium</i> spp.	Liliaceae	U.S. (d)	Olsen 1967:92, Kavasch 1979:156
Lavender	[ <i>Lavandula angustifolium</i> , <i>L. stoechas</i> ]	Lamiaceae	U.S.: Northeast, etc.	Kephart 1921:246; Granett 1940; Mabey et al. 1988:161
Lime (oil)	[ <i>Citrus aurantifolia</i> ]	Rutaceae	India (e)	Covell 1931:4
Parsley	<i>Petroselinum crispum</i>	Ammiaceae	Russia (d)	Hutchens 1992:151
Pennyroyal	<i>Hedeoma longifolium</i> , <i>Monardella odoratissima</i>	Lamiaceae	U.S.: West (d,e)	Moore 1979:121-123
Pennyroyal	[ <i>Mentha pulegium</i> , <i>Hedeoma pulegioides</i> ] (c)	Lamiaceae	India, U.S. (d,e)	Kephart 1921:246, Covell 1931:4, Matheson 1966:76
Peppermint (oil)	[ <i>Mentha piperita</i> ]	Lamiaceae	India; U.S.: Northeast (e)	Covell 1931:4, Granett 1940
Pine (oil or tar), oil of turpentine	[ <i>Pinus</i> ]	Pinaceae	India; U.S.: Northeast (e)	Covell 1931:4, Granett 1940
Pyrethrum (extract)	[ <i>Chrysanthemum cinerariifolium</i> , <i>C. coccineum</i> ]	Asteraceae	Canada, U.S. (e,f)	Covell 1931:4, Jaeger 1945:179
Quassia	[ <i>Quassia amara</i> ]	Simaroubaceae	U.S. (d)	Kephart 1921:247
Rose geranium (oil)	[ <i>Pelargonium</i> ]	Geraniaceae	India (e)	Covell 1931:4

Rosemary	<i>[Rosmarinus officinalis]</i>	Lamiaceae	U.S.: Northeast	Granett 1940
Sandalwood (powdered)	<i>[Santalum]</i>	Santalaceae	India (e)	Covell 1931:4
Sassafras	<i>[Sassafras albidum]</i>	Lauraceae	U.S. (d)	Kephart 1921:246
Thuja (arborvitae) (oil)	<i>[Thuja]</i>	Cupressaceae	India (e)	Covell 1931:4
Thyme (oil)	<i>[Thymus ?vulgaris]</i>	Lamiaceae	Canada; U.S.: Northeast (e,f)	Granett 1940, Jaeger 1945:179
Wormwood	<i>[Artemisia]</i>	Asteraceae	U.S.: Northeast	Granett 1940

FOOTNOTES TO TABLE 2.

- a. Refers to the locale of use, not necessarily the locale of collection or cultivation of the plant.
- b. This could be an error for *Cymbopogon*, or might represent a correct report of the North American *Collinsonia canadensis*.
- c. There may be some confusion of the two species of pennyroyal in the literature, and some authors do not identify the species.
- d. Used for protection against biting insects in general, or taxa not stated.
- e. Used against mosquitoes.
- f. Used against biting midges.