**Aquatic Insects, D-BAIT Lesson**

**Notes to Accompany Powerpoint Presentation**



1: Aquatic Insects

- Teacher and student sampling aquatic insects at a pond using everyday items.

2: What is an Insect?

- Insects are organisms within the class Insecta. Insects and other classes such as Arachnids and Crustaceans are within the Phylum Arthropoda. Arthropods are one Phylum within the animal kingdom.

- Animals are heterotrophs meaning they do not make their own energy.

- Animals obtain energy with internal digestion, unlike the heterotrophic fungi.

- Arthropods are animals with an exoskeleton and jointed legs.

- Insects are arthropods with external mouthparts, three body regions, and six legs.

- The three insect body regions have distinct roles.

- The head houses organs for sensing the environment and for feeding.

- The thorax has legs and wings for locomotion and houses the muscles that drive these.

- The abdomen is devoted to reproduction and digestion.

3: Aquatic Insect Evolution

- Insect in photograph is a larval Neuroptera, or a net-winged insect. Adults are terrestrial and fly.

- Most aquatic insect groups are aquatic in the immature stage. Some have aquatic adults as well, while some have terrestrial adults.

- The most primitive insects do not have wings, but there are very few aquatic species in these groups. All insect Orders with significant numbers of aquatic species are winged as adults.

- Mayflies and dragonflies + damselflies are old-winged insects that cannot fold their wings against their bodies. They have a primitive flight muscle mechanism.

- More recently-evolved insects, the new-winged insects, have muscles attached directly to the base of the wing and they are able to draw the wings against the body. This allows them to use more types of habitats in the adult stage.

- Stoneflies, True Bugs.

- The most advanced insects are new-winged insects with complete metamorphosis allowing the immature stages and the adult stage to be completely different.

- True Flies, Caddisflies, Beetles, Net-winged insects.

4: Insect Life Cycles

- All insects grow by shedding their exoskeleton several times.

- Incomplete metamorphosis involves doing so while growing adult features slowly.

- Wing buds appear and get larger with each molt.

- Immature stages, called nymphal stages, are similar to the adult form.

- Complete metamorphosis of later evolved insects allows for the immature stages, called larval stages, to be completely different from the adult stage. This allows larvae to specialize in feeding and growing and adults to specialize in dispersing and reproducing.

- Aquatic insects with both complete and incomplete metamorphosis have species that have adults that aquatic and species that have terrestrial adults.

5: Habitats & Challenges

- Habitat is the ecological area that a species lives in. This influences the resources available and the challenges that a species faces.

- Different habitats have different benefits and different challenges. There is much variety in aquatic habitats.

- Ponds and lakes are still water which may have a low oxygen content. Breathing in order to conduct respiration is therefore a challenge for aquatic insects in these habitats. However, there may be a high density of plants and dead plant matter in ponds and lakes providing food and hiding places.

- Streams and rivers are moving water which may have a high oxygen content. Moving water however often has a much lower plant density. Hanging on to the substrate may be a challenge in faster-moving waters.

6: Life in the River Continuum – Headwater streams

- Stream habitats have different conditions depending on how far upstream or downstream the insect lives. Different types of insects are adapted to different places along this continuum.

- Headwater streams are small and often fast-flowing. They are often well-shaded, which leads to lower plant density and a cool temperature. The fast water causes a stony bottom substrate. They have a high oxygen concentration. There is much dead plant material deposited but this is moved into small pockets by the water.

7: Life in the River Continuum – Mid-reach streams

- Mid-reach streams are fed by many headwater streams and so are larger. They have a slower water velocity than headwater streams. They are larger and deeper than headwater streams. The substrate may be rocky, sandy, or silty depending on the water speed and the local geology. There are more plants and more sunlight but they may be partially shaded through part of the day. They are warmer and have a lower oxygen content than headwater streams.

8: Life in the River Continuum – Lower reaches/rivers

- Low-reach rivers are fed by several mid-read streams.

- These rivers are wide, may be deep, and are mostly unshaded and may contain murky water.

- Living aquatic plants may be plentiful, creating an abundant resource not found in smaller tributaries.

- The low speed of these rivers means that hanging on is not a challenge and directed swimming becomes important.

- Lower oxygen may make breathing a challenge.

9: Food Webs

- A food web is the matrix of connections between organisms formed by energy transfer. It is a food map of “who eats who?” in a particular habitat.

- The most simple depiction of a these connections is a food chain.

- Plants are autotrophs that harness energy from sunlight.

- Herbivores are heterotrophs that get energy by ingesting plants.

- Primary carnivores get energy by eating herbivores.

- Secondary carnivores get energy by eating smaller primary carnivores.

- Tertiary carnivores eat secondary carnivores.

- Dead carnivores are decomposed by fungi, which are heterotrophs like animals.

- Nutrients from decomposition by fungi are taken up by plants.

10: Aquatic Food Webs

- While the food chain is a useful mental model for understanding nutrient and energy flow, actual food webs in nature are much more complex, and are formed by many inter-woven food chains.

- There are many different organisms at each level. The interconnections depend upon the species involved, and together form a food web.

- Some aquatic food webs can be very complex, such as this map of “who eats who?” from a lake with 92 different studies species found within 4 trophic levels.

11: Adaptation

- Organisms, including aquatic insects, adapt to challenges they face in their habitats and their food webs. Those species that do not die out and become extinct.

- Adaptation is a modification of a trait in a population over time. It is not a change to an individual.

- Slight changes that allow greater reproductive success (more successful offspring) lead to an increased representation of the altered trait in subsequent generations.

- Over time, different habitat and food web challenges lead to diversification. The pictured species of preying mantids have evolved to have different forms that allow them to perform well as sit-and-wait predators mimicking leaves or flowers.

- Aquatic insects need to move breathe, eat and avoid predation in different habitats and different aquatic food webs. Different adaptations can be seen in these different conditions. The different adaptations function in different ways.

12: Adaptation

- An example of adaptation can be seen in the way that the same basic parts of an insect’s leg have been modified for different functions. The structure of the leg suggests how the insect moves.

1, insect leg lengthened for rapid running.

2, grasshopper leg with modified hinge and large muscular femur.

3, digging leg of a scarab beetle.

4, paddle-like swimming leg of an aquatic beetle.

5, raptorial front leg of a mantid. Note coxa has been recruited as a leg segment.

6, basket-like bee leg that facilitates collection of pollen.

13: Adaptation

- Mouthparts of insects have modified the same basic parts to serve different functional roles for different food sources.

A, grasshoppers have a fairly ancestral, generic form of insect mouthparts.

B, bees have mouthparts suitable for lapping nectar of flowers.

C, moths have the mouthparts extended into a coiled proboscis that is extended to suck nectar. Note that the most primitive moths still have grasshopper-like mouthparts and scrape lichen from rocks.

D, mosquitos (True Flies) have piercing-sucking mouthparts for blood-feeding.

14: Adaptation of Mouthparts

- The chewing mouthparts of this mayfly nymph are used to chew filaments of algae.

- Adults of mayflies do not eat, and their mouthparts are often greatly reduced. This suggests that there is a metabolic cost to structures---advantageous to reduce what is not used.

15: Adaptation of Mouthparts

- The hellgrammite is the larva of a net-winged insect called a dobsonfly.

- The mandibles have been modified to have a sickle-like shape for catching and subduing prey.

- These are large intimidating aquatic insects that do hurt when they bite humans. The pain is worth the catch however, for they are excellent bait for fishing.

16: Adaptation of Mouthparts

- True Bugs have forward-mounted piercing-sucking mouthparts.

- The mouthparts of this Eastern toe-biter are very stout and can be jabbed between plates in the exoskeleton of other insects.

- The mouthparts contain two inner channels. One pumps flesh-liquifying saliva into the prey, while the other simultaneously sucks up the resulting protein-rich liquid.

17: Adaptation of Mouthparts

- Head of a black fly larva are modified into fans to collect organic material flowing by in fast-moving water.

- This adaptation works in this habitat because there is much organic matter passing quickly, so they filter a large volume of water. There is a large return in food for little energetic input as they do not move to seek food.

- Question on constraints: they must stay in place out in the current. Abdomen modified to remain attached to rocky substrate.

18: Other Adaptations for Feeding

- There are many unusual and surprising adaptations in aquatic insects.

- Water scorpions are not venomous, their tail is for breathing. They are true bugs and thus have piercing-sucking mouthparts. They also have raptorial forelegs similar to a mantid.

- Some caddisflies spin webs that strain organic material from flowing water. More recently evolved families of caddisflies spin a net beside the enclosed web that they live within.

- dragonfly nymphs have a hinged lower jaw that quickly articulates out to catch prey and draw them back to the head for consumption.

19: Avoiding Predators

- Aquatic insects can use physical or behavioral adaptations to avoid being eaten.

- Stonefly nymphs are flattened and cryptically-colored to blend in against surfaces.

- The larvae of caddisflies, the sister Order to the moths, are able to spin silk.

- Larvae of the more primitive families of caddisflies remain within horn-shapes nets that are spun. More recently-evolved caddisflies have larvae that spin materials together with their silk and use this as a mobile armored home.

20: Avoiding predators

- Some aquatic insects live in places that make them harder to reach, such as underneath rocks.

- Some mayflies burrow into the substrate to avoid predation.

- Some flies develop within temporary pools of water in tree holes or tire tracks in the mud. Fish predators cannot survive in such ephemeral pools. However, the life cycle must be short to be completed before the water dries up.

21: Adaptations for Locomotion

- Moving in the water presents different challenges than moving on land. Adaptations reflect these challenges.

- Water pennies are beetle larvae. Their dorsal exoskeleton is flattened and extended into a hydrodynamic shape that lowers the resistance of fast-flowing water.

- Many insects have “teeth” on their tarsi (feet) to help hang on to the substrate.

- Water striders have tarsi covered with hydrophobic hairs that take advantage of the surface tension of water to walk on the water.

22: Adaptations for Swimming

- While many insect larvae and adults swim in an expected manner, there are some more extreme modifications to do so.

- Predacious diving beetles have legs that are modified into a flattened paddle-like shape. Hairs are placed to expand the surface area further.

- Dragonfly nymphs can draw water into their abdomens and expel it rapidly to escape predators.

23: Adaptations for Hanging On

- Caddisfly larvae live in nets or shells. Both are spun from silk glands.

- They have large claws on the end of their abdomen to cling to the inside of their domicile.

24: Adaptations for Breathing

- Water has much less oxygen than air. Many aquatic insects have gills that are able to extract oxygen from the water. This works best in water with a high oxygen content.

- More efficient in headwater and mid-reach streams. However, some insects with gills do live in less-oxygenated still water but they need more efficient or larger gills.

- Damselfly nymphs have gills at the end of their abdomen. Dragonfly nymphs have internal gills that they draw water to. The pictured mayfly nymph has gills along the sides of its abdomen.

25: Adaptations for Breathing

- Some aquatic insects without gills use a snorkel-like air tube to replenish their air supply.

- Water scorpions visit the near-surface water regularly to draw in a supply of air.

- Larvae of rat-tailed maggots (true flies) have a long extendable tube that draws air in from above the surface. These maggots are capable of surviving in extremely polluted and low-oxygen conditions.

26: Adaptations for Breathing

- Some insects carry bubbles of air with them underwater.

- Hydrophobic hairs help trap air against the body. This air supply must be replenished often.

- Predacious diving beetles hold a pocket of air between their dorsal body (“back”) and their wing covers. The bubbles seen in the photograph are excess air attached to this pocket.

- Water boatmen (true bugs) have hairs that hold a pocket of air against their ventral surface (“front”).

- Spiracles on the sides of the insects breathe directly from the air pockets.

- This method greatly changes the buoyancy of the insect, presenting additional challenges.

27: Interesting Aquatic Insects: Dragons & Damsels

- Dragonfly and damselfly nymphs (they are in the same insect Order) are important predators in aquatic habitats.

- Both have extendable lower jaws (labial mask) that is a hunting appendage on their head.

- Both use gills to breathe.

- Dragonflies have aquatic jet propulsion.

28: Dragonfly Nymph Eating

- Immature dragonflies are able to subdue and eat other large insects, tadpoles, and even fish.

- Link to YouTube video shows this—excellent video, 1 min 38 sec long.

29: Mayflies

- Mayflies are primitive insects. The adults have old-style wings that remain extended.

- Adults may live only about a day and do not feed.

- Some species have mass synchronized emergences from the water. Their short adult lives require this in order to find mates.

- Many species are intolerant of pollution. The number species of mayflies is therefore used as part of an important index of water quality.

30: Stoneflies

- Also intolerant of pollution.

-Require cool, shaded, well-oxygenated water.

- Require rocky substrate, so where soil is silty they are only found in headwater streams.

- Some species have adults emerge in late winter, possibly to avoid vertebrate predators that are more numerous in the spring.

31: True Bugs

- Many different families that are aquatic.

- Adult giant water bugs are aquatic but disperse by flying between bodies of water. They are attracted to bright lights in mid-summer during these flights.

- Male giant water bugs carry eggs on their backs (upper left).

- Water scorpions use a breathing tube (upper middle).

- Water boatmen have modified paddle-like legs (lower right).

- Water boatmen have also greatly reduced antennae as these do not function in the water (upper right). Suggests that structures carry a metabolic cost and that reducing unused appendages is advantageous.

- Water striders can walk on water (lower left).

32: Beetles

- Many beetle families are aquatic either as larvae or during entire lifecycle.

- Whirligig beetles are hydrodynamic and skim the surface. They have a pair of eyes above water and a pair below (left).

- Larval water penny adapted to swift currents.

- Adult water scavenger beetles have a keel that may help to move forwards as they alternate swimming strokes from side to side (top right).

- Predacious diving beetles hold air bubbles to breathe from. They swim with synchronized strokes.

33: True Flies

- Very diverse adaptations. Different families have larvae that are found in almost every type of fresh water.

- Can be used as a biological indicator of water quality.

- Some non-biting midges (Chironomidae, center) are red because their haemocoel (“blood”) contains an iron-rich oxygen-binding molecule similar to that in mammals.

34: Caddisflies

- Sister Order to the moths and adults look like drab moths. Also spin silk, but from their legs.

- Larvae use silk to spin nets, webs, or armored mobile homes.

35: Other insect Orders have aquatic species.

- There are aquatic moths with caterpillars that feed within submerged plants.

- A tiny fairy wasp is a parasitoid of aquatic beetle eggs. It swims with its wings.

36: Biological Indicators

- Because the adaptations of insects determine how much pollution (and lowered oxygen, siltation, warming) that they can tolerate, the insects present can be a biological indicator of water quality.

- While scientific probes can measure water quality metrics rapidly, they only capture a snap-shot of the conditions. The insect community reflects the conditions over a much longer period.

- One common index, the EPT index, uses the diversity of mayflies, stoneflies, and caddisflies, as many species within these groups are not tolerant of pollution. If there are many different species in these groups, the water is likely not polluted.

37: Biomimicry & Humans in the Food Web

- When humans go fishing, they are inserting themselves into the aquatic food web.

- People that fly fish strive to tie flies that mimic insects that fish will “eat.” This requires understanding where different insects are, what time of year they are present, and how they act.

- With a greater understanding of fish – insect interactions and insect functions such as how they breathe, swim, feed, comes greater fishing success.

38: Biomimicry-Inspired Design

- Getting a fish to attack a lure will be more successful if the lure matches the behavior, location and timing, and appearance of the fishes natural prey.

- If you know how an insect is adapted to live underwater, you can design a lure that mimics the functioning of that insect. This is the essence of biomimicry-inspired design.

39: Using Aquatic Entomology Knowledge

- This knowledge of aquatic entomology can be used within the framework of the D-BAIT lesson that uses biomimicry to design a fishing lure that mimics the function of an aquatic insect.

- This knowledge can also be used along with aids to identify aquatic insects to calculate an index of water quality based upon the insects that are found in the water.