CHAPTER 11-9
AQUATIC INSECTS: HOLOMETABOLA – COLEOPTERA, SUBORDER ADEPHAGA

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Figure 1. ***Lancetes angusticollis*** adults on moss, South Georgia in the Antarctic. ***Lancetes angusticollis*** has a two-year life cycle, with overwintering possible in three life stages – aquatic larvae, terrestrial pupae (not proven), and aquatic adults. Note the air supply at the tip of the abdomen. This external air supply makes it necessary for these beetles to cling to vegetation, when they are not swimming, to avoid floating to the surface, hence their use of mosses. Photo by Roger S. Key, with permission.

COLEOPTERA BACKGROUND

The Coleoptera seem to have a somewhat closer relationship to terrestrial life than other aquatic bryophyte dwellers. First of all, they get their air from the atmosphere or underwater plants where they grab an air bubble (Figure 2). They can accumulate air as bubbles under the **elytra** (hardened forewings; wing covers), through the **plastron** (breast plate breathing apparatus; Figure 3) (Oliveira de Sousa *et al*. 2012), or an anal bubble. The **plastron** is a ventral structure that acts as a physical gill by using various combinations of hairs, scales, and undulations projecting from the cuticle. This apparatus holds a thin layer of air along the outer surface of the body (Figure 3). In all three of these mechanisms, the nitrogen in the air bubble diffuses into the water slowly while the replacement oxygen diffuses into it 2-3 times as fast (Rich Merritt, pers. comm. 28 January 2015). Thus, as the insect uses up the oxygen from the bubble, the water replaces it by oxygen diffusion for a reasonable period of time. The CO_2 from respiration enters the bubble and rapidly diffuses into the water, having little effect on bubble size. Many beetles attach an anal gas bubble (Figure 1, Figure 18-Figure 19) that uses this diffusion mechanism. They may have hairs that help hold the bubble in place. (See **Elmidae** in Coleoptera, Suborder Polyphaga, for details of the plastron functioning in that family.)

Figure 2. ***Berosus luridus*** adult on moss where air bubbles from photosynthesis can be used to replenish the air supply. Photo by Tim Faasen, with permission.

Figure 3. ***Chaetarthria siminulum*** adult with plastron. When the plastron is full of air, the beetle must cling to vegetation in order to descend into the water column. Photo by Gerard Visser <www.microcosmos.nl>, with permission.

Nearly all aquatic **Coleoptera** go to land to pupate (Leech & Chandler 1956; Pennak 1978; Erman 1984), then return to the water as adults. Others clamber about on the surface of the plants. Some of these are associated with floating plants, including ***Ricciocarpos natans*** (Figure 4) (Scotland 1934). To get below the surface requires muscle action to break the surface tension (Leng 1913).

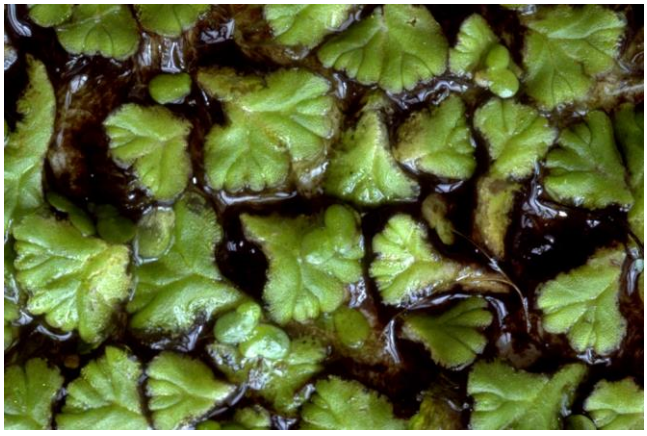

Figure 4. ***Ricciocarpos natans***, a floating liverwort. Photo by Jan-Peter Frahm, with permission.

Percival and Whitehead (1930) noted that the mosses in streams in the UK were very important to both larvae and adults of the small Coleoptera. In 1949, Badcock indicated that beetles were more common among mosses than associated with stones, especially loose stones. Ogbogu (2000) found **Coleoptera** among the insects associated with ***Fontinalis*** (Figure 5) in an intermittent reservoir spillway in Ile-Ife, Nigeria. Many of the **Coleoptera** in rivers of northwest Spain prefer moss as a substrate, as indicated by both species richness and abundance (Fernández-Diaz 2003; Sarr *et al*. 2013). They attributed this to the abundance of food available for the herbivores (Passos *et al*. 2003; Sarr *et al*. 2013). This applied particularly to the **Elmidae** and **Hydraenidae**.

Figure 5. ***Fontinalis antipyretica*** on rocks of a stream bed. Photo by Betsy St. Pierre, with permission.

Among the most common of these bryophyte dwellers are the **Elmidae** (Figure 6), small beetles only a few mm in length (Percival & Whitehead 1930; Glime 1994). But many studies miss the small **Coleoptera** that live among the bryophytes, necessitating special collecting techniques for such habitats as submerged roots, wood, and mosses (Zaťovičová *et al*. 2004). Zaťovičová and coworkers found 13-61% more species when they used qualitative sampling that included these habitats.

Figure 6. **Elmidae** adult, one of the most common of beetle families among bryophytes. Photo by Stephen Moore, Landcare Research, NZ, with permission.

Whereas mosses in streams and lakes are not especially important for beetles, bogs and fens have greater

species numbers. Some live in the acidic pools, some burrow into the moss mats, and some run about the surface. The **Dytiscidae** (Figure 18-Figure 55) are particularly important in the pools. These bog dwellers, although often not adapted to a submerged aquatic habitat, will be included here.

Jones (1950) did extensive gut analysis of insects from the River Rheidol and found that none of the **Coleoptera** had mosses (***Fontinalis antipyretica***, Figure 5) in their guts, although **Plecoptera** and **Trichoptera** did. Rather, these **Coleoptera** were all carnivores.

Suborder Adephaga

This suborder is comprised of a group of highly specialized beetles.

Carabidae – Ground Beetles

The **Carabidae** forms a large family (>40,000 species) (Ground Beetle 2015), ranging 0.7-66 mm long (Bartlett 2004a). Despite this large number of species, they are mostly either shiny black or metallic and have ridged elytra (Ground Beetle 2015). Their distribution is worldwide, but records from Africa and Asia are scant. Typical homes are under tree bark, under logs, and among rocks or sand by the edge of ponds and rivers. Many expel an especially noxious and painful liquid for their defense. They are predators, often rapidly chasing their prey, usually at night (Bartlett 2004a).

These are not aquatic beetles, but they do live in bogs (Boyce 2011). In Dartmoor, UK, ***Agonum ericeti*** (Figure 7) prefers mires that have both ***Sphagnum*** (Figure 7) hummocks and warm, bare peat. Here they run around on the bog surface and are one of the most "important" species in the bog. They occur only where there are abundant bog mosses.

Figure 7. ***Agonum ericeti*** adult, a mire dweller, on ***Sphagnum.*** Photo by Niels Sloth, with permission.

Pterostichus rhaeticus (Figure 8) prefers to live among ***Sphagnum*** (Figure 7) of a blanket bog (Boyce 2011). ***Pterostichus diligens*** (Figure 9) likewise lives in blanket bogs, but lives in litter as well as among mosses. ***Acupalpus dubius*** is sometimes restricted to the moss ***Drepanocladus aduncus*** (Kopecky 2001).

Figure 8. ***Pterostichus rhaeticus*** adult, a blanket-bog dweller. Photo by Niels Sloth, with permission.

Figure 9. ***Pterostichus diligens*** adult, an inhabitant of mosses and leaves in blanket bogs. Photo by Niels Sloth, with permission.

Figure 10. ***Acupalpus dubius*** on leafy liverworts and mosses. Photo ©Roy Anderson <habitas.org.uk>, with permission.

Figure 11. ***Drepanocladus aduncus***, home for ***Acupalpus dubius***. Photo by Bob Klips, with permission.

Gyrinidae – Whirligig Beetles

This family is aptly named for its behavior of skating in whirling patterns on the water surface. The most unusual feature of this family is the eyes. They are divided so that two eyes are above the water and two are below, protecting the beetles from predators above and permitting them to see what is beneath them (Gyrinidae 2015). Their size ranges 3 to 18 mm long (Whirligig Beetles 2014). They eat insects that fall into the water, sensing the vibrations of their struggles by using their antennae. They are worldwide, with a heavy concentration in Europe.

But even these insects sometimes use mosses. At least some members of the **Gyrinidae** (Figure 12-Figure 14) use mosses as hiding places during the day (Leng 1913). And in the Appalachian Mountain, USA, streams, the mosses may provide a refuge for ***Dineutus*** (Figure 12-Figure 14) during times of high flow (Glime 1968).

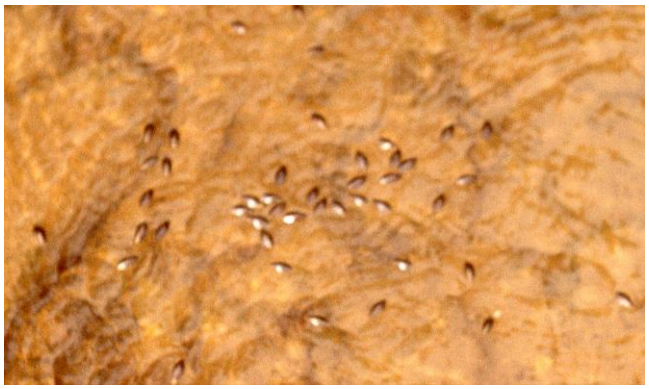

Figure 12. ***Dineutus discolor*** (whirligig beetles) on the water surface. Photo by Janice Glime.

Figure 13. ***Dineutus assimilis*** adult showing split eyes. Photo by Joyce Gross, with permission.

Figure 14. ***Dineutus*** larva, a genus that sometimes occurs among bryophytes when it is resting. Photo by Bob Henricks, with permission.

Haliplidae – Crawling Water Beetles

The **Haliplidae** are clumsy swimmers, alternating the motion of their legs (Haliplidae 2014). Hence, they move about mostly by crawling. The adults are convex on the dorsal side and range 1.5-5.0 mm long. The hind legs have large coxal plates and are immobile. The primary function of these legs seems to be that of storing air, supplementing the air stored under the elytra. The larvae eat only algae, but the adults are omnivorous. They live among aquatic vegetation around the borders of small ponds, lakes, and quiet streams. Their worldwide distribution is similar to that of the **Scirtidae**, with the greatest diversity known in Europe (Haliplidae 2015).

These are mostly not bryophyte dwellers, but the genus ***Haliplus*** (Figure 15) still benefits from the presence of ***Sphagnum*** (Figure 7). ***Haliplus variegatus*** (Figure 16) in Poland lives in canals that are created by beavers in floating ***Sphagnum*** mats (Buczyński *et al.* 2014).

Figure 15. ***Haliplus*** larva. Some members of this genus live in bogs and ***H. variegatus*** lives in beaver canals in floating ***Sphagnum*** mats. Photo by Dana R. Denson, Florida Association of Benthologists, with permission.

Figure 16. ***Haliplus variegatus*** adults, inhabitants of beaver canals in floating ***Sphagnum*** mats of Poland. These color phases and the spots can help to camouflage the beetles among the mosses. Photo by Stefan Schmidt, through Creative Commons.

In my own studies (Glime 1968) in the Appalachian Mountain, USA, streams, I found the genus ***Brychius*** (Figure 17). The generic name suggests a possible moss habitat, but I was unable to find additional information on the habitat.

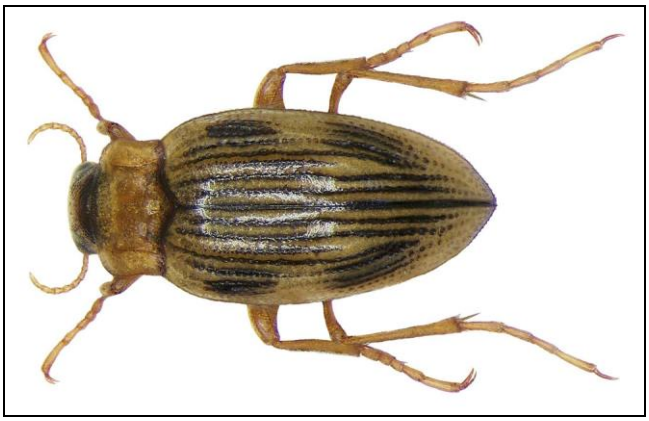

Figure 17. ***Brychius elevatus*** adult, a genus with moss inhabitants in Appalachian Mountain, USA, streams. Photo by Udo Schmidt, through Creative Commons.

Hygrobiidae – Squeak Beetles

This small family has only one genus, ***Hygrobia***, with six species, and is distributed in Europe, North Africa, China, and Australia (Hygrobia 2014). ***Hygrobia*** adults make a grating noise, earning them their name of squeak beetles (Pendleton & Pendleton 2014). Their size is moderate (8.5-10 mm). They are most common in stagnant water, where they walk or swim; they do not dive (Watson & Dallwitz 2003a). They obtain their oxygen from the air collected and stored under the elytra. ***Hygrobia hermanni*** (Figure 18) reaches large populations at pond margins where it lives among the submerged ***Sphagnum*** (Figure 39) (Denton 2013).

Figure 18. ***Hygrobia hermanni*** adult, an inhabitant of submerged ***Sphagnum***. Note the anal air bubble. Photo by Trevor and Dilys Pendleton, with permission.

Dytiscidae – Predaceous Diving Beetles and Noteridae – Burrowing Water Beetles

The **Noteridae** are often included with the **Dytiscidae** and I will do so here because it makes the discussion easier. The larvae of **Dytiscidae** are known as water tigers. They are passive predators, waiting quietly until a prey organism passes nearby (Dytiscidae 2014). On the other hand, several members of the family are eaten by humans in China, Japan, and Mexico, as well as other places in the world. This worldwide family has a large range of sizes (1.2-40 mm long) (Bartlett 2004b). They are distributed throughout the world, but with the best known concentrations in North America, Europe, and Australia (Dytiscidae 2015). The larvae live in the water, but they climb to land and bury themselves in the mud for pupation, returning to the water as adults.

The adult **Dytiscidae**, like other beetles, lack true gills. Instead, they carry a bubble of air with them as they descend down the water column. This bubble is either held against the body or stored under the **elytra** (outer hardened wings) (Figure 1). As oxygen is used up, nitrogen maintains the size of the bubble so that oxygen can diffuse into the bubble. When the bubble becomes too small, they must obtain another bubble from plant surfaces or the water surface by exposing the tip of the abdomen (Figure 19).

Figure 19. ***Rhantus suturellus*** adult replenishing air supply at surface. Photo by Niels Sloth, with permission.

Based in my own studies on moss-dwelling aquatic insects in the Appalachian Mountains, USA, it seemed that the predaceous diving beetles (**Dytiscidae**) do not typically hang out among the bryophytes. But many of the species occur in mossy wet areas, especially associated with bogs and fens. Usinger (1974) describes three types of ovipositors in the **Dytiscidae**. Those with a long ovipositor are able to inject their eggs into moss mats growing in the water. And some species even ingest mosses occasionally (Jones 1949).

Roger Key (pers. com. 31 October 2014) considers the primary role of bryophytes in the life of the predaceous aquatic beetles to be that of a structural component, a place for cover to escape predators. But these beetles are mostly predators themselves (Figure 20). In some cases the mosses are important as a place to hang or climb to avoid being carried to the surface by their air supply – the plastron apparatus or air layer under the elytra. For example, ***Lancetes*** in South Georgia may make use of mosses, among other anchored substrata, to get back under the surface or to stay there when it is not actively swimming. In places like South Georgia, mosses are the predominant, if not the only, vegetation at the margins of streams, hence providing these roles for aquatic beetles there.

Figure 20. ***Dytiscus*** larva eating young fish. Photo by Roger S. Key, with permission.

Graphoderus zonatus (spangled diving beetle; Figure 21) occurs where ***Fontinalis*** (Figure 5) provides the major vegetation in a heathland mire in Hampshire, UK (Roger S. Key, pers. comm. 31 October 2014). This diving beetle is frequently found associated with the mosses and can be collected by shaking the mosses over a container. The bryophyte role, as suggested above, is one of cover.

Oreodytes davisii (Figure 22) and ***O. sanmarkii*** (Figure 23) both live among aquatic bryophytes in a stream in Yorkshire, UK (Gilbert *et al*. 2005). ***Oreodytes rivalis*** may occasionally even ingest mosses such as ***Fontinalis antipyretica*** (Figure 5) (Jones 1949), perhaps in their attempts to capture one of the other invertebrates dwelling there.

Figure 21. ***Graphoderus zonatus*** adult in a heathland mire in Hampshire, UK. Photo by Roger S. Key, with permission.

Foster (1992) found ***Hydroporus umbrosus*** (Figure 24) among mosses at the edge of a pond in Inner Hordaland, Norway. Usinger (1974) describes the small members of the genus ***Hydroporus*** as able to occupy moss-covered seepages no bigger than a hand. Buczyński *et al.* (2014) reported ***H. incognitus*** (Figure 25) from ***Sphagnum*** bogs (Figure 26) in Poland. In spring-fed boggy areas one can find ***Hydroporus longulus*** (Figure 27) among mosses and leaves (Denton 2013).

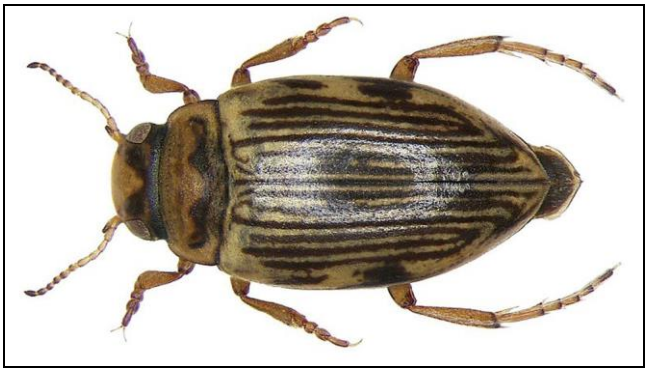

Figure 22. ***Oreodytes davisii*** adult, a bryophyte dweller in UK streams. Photo by Udo Schmidt, with permission.

Figure 23. ***Oreodytes sanmarkii*** adult, a stream bryophyte dweller in the UK. Photo by Christoph Benisch <www.kerbtier.de>, with permission.

Figure 24. ***Hydroporus umbrosus*** adult, a moss dweller at the edge of ponds in Norway. Photo by Niels Sloth, with permission.

Figure 25. ***Hydroporus incognitus*** adult, an inhabitant of ***Sphagnum*** bogs in Poland. Photo by Niels Sloth, with permission.

Figure 26. ***Sphagnum*** blanket bog, home to many kinds of beetles. Photo through Creative Commons.

Figure 27. ***Hydroporus longulus*** adult, a beetle one can find among mosses in spring-fed boggy areas. Photo by Tim Faasen, with permission.

Graphoderus zonatus (Figure 28) in North Hampshire, UK, lives in a variety of habitats, particularly in ***Sphagnum***-dominated (Figure 39) lake margins (Denton 2013).

Figure 28. ***Graphoderus zonatus*** adult with ***Sphagnum***. Photo by Niels Sloth, with permission.

Moors, Bogs, and Fens

These three habitats are partially aquatic, providing wet or damp bryophytes and pools where there may be submerged bryophytes. **Moors**, a term used more commonly in Europe, are upland habitats including heathlands and fens and characterized by low vegetation and acidic soils (Moorland 2014). The term **bog** has a mixed history, with North Americans using a much broader definition than that of the northern Europeans. Until relatively recently, North Americans tended to include any wetland with ***Sphagnum*** as a bog. English language dictionaries go even further to define a bog as any muddy or spongy wetland. The more restrictive European definition is a habitat that is dominated by ***Sphagnum*** and receives only precipitation as a source of new nutrients. By contrast, a **fen** may have ***Sphagnum*** or other dominant bryophytes, but it receives nutrients through surface or ground water in addition to precipitation. Most of the habitats that North Americans have called bogs (including most current definitions and websites on the internet) are actually **poor fens**, *i.e.*, wetland habitats with low nutrients, ground or surface water, and ***Sphagnum*** species similar to those of true bogs.

Fens and bogs provide habitats for a number of **Dytiscidae** and provide the most common associations with bryophytes. The genus ***Agabus*** is among these common inhabitants (Nelson 1996). ***Agabus affinis*** (Figure 29) can be considered a characteristic species, a **tyrphobiont** (species living only in peat-bogs and mires) in high moors (Hebauer 1974), often accompanied by ***A. unguicularis*** (Figure 30), in the moss lawns of lowland fens and bogs of Ireland (Nelson 1996) and flooded ***Sphagnum*** (Figure 39) (Denton 2013). In Scotland ***A. unguicularis*** occurs in peaty water with mosses or other dense vegetation (Knight 2014). ***Agabus melanocornis*** is less common and occurs in mossy drains, fens, and bogs (Nelson 1996). ***Agabus melanarius*** (Figure 31) is easily overlooked in North Hampshire, UK, where it lives in shallow water with mosses.

Figure 29. ***Agabus affinis*** adult with ***Sphagnum***. Photo by Tim Faasen, with permission.

Figure 30. ***Agabus unguicularis*** adult, a common inhabitant of bogs and fens, carrying an anal air bubble. Photo by Niels Sloth, with permission.

Figure 31. ***Agabus melanarius*** adult, a species from shallow water among mosses. Photo by James K. Lindsey, with permission.

In contrast to other bryophyte habitats, bogs are a mix of terrestrial and aquatic microhabitats that provide homes for a number of **Dytiscidae**. Brink and Terlutter (1983) found ***Dytiscus lapponicus*** (Figure 32-Figure 34), ***Hydroporus tristis*** (Figure 35), ***H. erythrocephalus*** (Figure 36), and ***Acilius canaliculatus*** (Figure 37), as well as **Noteridae** (burrowing water beetles, sometimes included in the **Dytiscidae**) – ***Noterus crassicornis*** (Figure 38), to be acid **tyrphophiles** (characteristic of bogs but not confined to them) associated with ***Sphagnum cuspidatum*** (Figure 39). ***Acilius*** is one of the genera with a long ovipositor that permits egg-laying among mosses and other substrata (Usinger 1956). These eggs are laid in the water and sometimes out of water. From Dartmoor, UK, Boyce (2011) also reported ***Hydroporus tristis*** in small, peaty pools that had ***Sphagnum*** (Figure 39). Boyce also found ***Hydroporus gyllenhalii*** (Figure 40) among ***Sphagnum*** in bogs and in small peat pools that likewise had at least some ***Sphagnum*** in both undisturbed and eroded blanket mires. ***Hydroporus obscurus*** (Figure 42-Figure 43) was more restricted, living only in relatively pristine blanket bogs where it lived in small ***Sphagnum***-dominated peat pools.

Figure 32. ***Dytiscus lapponicus*** larva, a species associated with ***Sphagnum cuspidatum***. Photo by James K. Lindsey, with permission.

Figure 33. ***Dytiscus lapponicus*** adult with mosses and aquatic plants. Photo by Niels Sloth, with permission.

Figure 34. ***Dytiscus lapponicus*** adult with mosses and aquatic plants. Photo by Niels Sloth, with permission.

Figure 35. ***Hydroporus tristis*** adult amid aquatic mosses. Photo by Tim Faasen, with permission.

Figure 36. ***Hydroporus erythrocephalus*** adult with leaf and ***Sphagnum***. Photo by Tim Faasen, with permission.

Figure 37. ***Acilius canaliculatus*** adult, a species associated with ***Sphagnum cuspidatum*** (Figure 39). Photo by Niels Sloth, with permission.

Figure 38. ***Noterus crassicornis*** adult on leaf litter in stream. Photo by Niels Sloth, with permission.

Figure 39. ***Sphagnum cuspidatum***, home for some **Dytiscidae** and **Noteridae**. Photo by Jan-Peter Frahm, with permission.

Figure 40. ***Hydroporus gyllenhalii*** adult, a species that lives among ***Sphagnum*** in bogs and bog pools. Photo by Niels Sloth, with permission.

In his studies in Central Europe, Hebauer (1974) similarly found ***Hydroporus pubescens*** (Figure 41) to be a tyrphobiont, as well as such tyrphobionts as ***Hydroporus obscurus*** (Figure 42-Figure 43) and ***H. melanocephalus*** in the high moors (Hebauer 1994).

The smallest member of Irish ***Hydroporus*** is ***H. scalesianus*** (Figure 44) (Nelson 1996). In the Appalachian Mountain, USA, streams, this genus lives among stream mosses (Glime 1968), whereas in Ireland it lives exclusively among mossy carpets of undisturbed fens, mires, and lake basins.

Figure 41. ***Hydroporus pubescens*** adult among ***Sphagnum***. Photo by Tim Faasen, with permission.

Figure 42. ***Hydroporus obscurus*** adult on ***Sphagnum***. Photo by Tim Faasen, with permission.

Figure 43. ***Hydroporus obscurus*** adult climbing on a moss. Photo by Niels Sloth, with permission.

Figure 44. ***Hydroporus scalesianus*** adult, the smallest ***Hydroporus***, on ***Sphagnum,*** from the high moors of Europe. Photo by Tim Faasen, with permission.

Other tyrphobionts in the high moors included ***Rhantus suturellus*** (Figure 19, Figure 45) (Hebauer 1974), a species also found in Poland in peaty pools (Boyce 2011). In Ireland, ***Graptodytes granularis*** (Figure 46) lives in mossy carpets of undisturbed fens, mires, and lake basins, but requires permanently wet mosses (Nelson 1996).

Ilybius crassus and ***I. aenescens*** (Figure 47-Figure 48) are tyrphobionts in European high moors (Hebauer 2994). ***Ilybius aenescens*** also occurs in flooded ***Sphagnum*** (Figure 39) of heathlands of North Hampshire, UK, but it is rare (Denton 2013). Boyce (2011) found that ***Ilybius montanus*** usually occur in shallow bog pools where there are dense growths of ***Sphagnum***. ***Ilybius fuliginosus*** (Figure 49) is quite ubiquitous and thus might be found hiding among the mosses (Tim Faasen, pers. comm. 20 October 2014). But ***Ilybius*** is not restricted to bogs and moors, appearing among mosses in Appalachian Mountain, USA, streams (Glime 1968).

Figure 45. ***Rhantus*** larva. Photo by Dana R. Denson, Florida Association of Benthologists, with permission.

Figure 46. ***Graptodytes granularis*** adult, dwelling in the high moors of Europe. Photo by Tim Faasen, with permission.

Figure 47. ***Ilybius aenescens*** adult among mosses. Photo by Tim Faasen, with permission.

Figure 48. ***Ilybius aenescens*** adult, a bog dweller. Photo by Niels Sloth, with permission.

Figure 49. ***Ilybius fuliginosus*** adult, a ubiquitous species that hides among vegetation, shown here on mosses. Photo by Tim Faasen, with permission.

Laccornis oblongus (Figure 50) is a flightless beetle that lives in Irish fens that lack open water (Nelson 1996). It occurs among wet moss carpets, especially those associated with clumps of sedges. ***Hydaticus seminger*** (Figure 51) is a dweller of typical mossy fens. This species is not frequent in North Hampshire, UK, but it does occur among flooded ***Sphagnum*** and in detritus pools (Denton 2013).

Figure 50. ***Laccornis oblongus*** adult, a flightless beetle known from moss carpets in Irish fens. Photo by Niels Sloth, with permission.

Figure 51. ***Hydaticus seminiger*** adult, a mossy fen dweller. Photo by Tim Faasen, with permission.

Floating moss carpets are often associated with bogs and fens. ***Bidessus grossepunctatus*** (Figure 52) is one of the inhabitants of these moss carpets in small lakes, ponds, fen pools, and mires (Nilsson & Holmen 1995).

Figure 52. ***Bidessus grossepunctatus*** adult, an inhabitant of floating moss carpets, on ***Sphagnum***. Photo by Tim Faasen, with permission.

Special techniques can facilitate collecting bog and fen species. Since bryophytes in these habitats are typically underlain by water, these semi-terrestrial beetles can be collected by depressing the mosses, creating a depression until they are covered by water (Nilsson & Holmen 1995; Knight 2014). The beetles can then be swept from the water with a tea strainer. Knight (2014) considers this technique especially useful for sampling **Hydraenidae** and small **Hydrophilidae**.

In the Japanese rice fields, many invertebrates find refuge. Some of these fields even have peat mosses. Such communities include ***Cybister japonicus*** (Figure 53-Figure 54) (Ohba 2009), a species eaten by humans in Japan (Dytiscidae 2014). These carnivores feed on insects such as Odonata in early instars, but starting in the third instar they feed on small vertebrates such as amphibia as well. In the last larval stage, they burrow into the peat moss and enter the pupation period.

Figure 53. ***Cybister japonicus*** adult, a species that hides among peat mosses in Japanese rice fields. Photo through Creative Commons.

Figure 54. ***Cybister japonicus*** larva, a species that hides among peat mosses in Japanese rice fields. Photo through Creative Commons.

Liodessus cantralli (Figure 55) lives in small pools in North America, but also lives in moss mats of fens (less often in bogs) (Larson & Roughley 1990). They are particularly associated with ***Drepanocladus*** *s.l.* (Figure 56) in depressions in the moss mats.

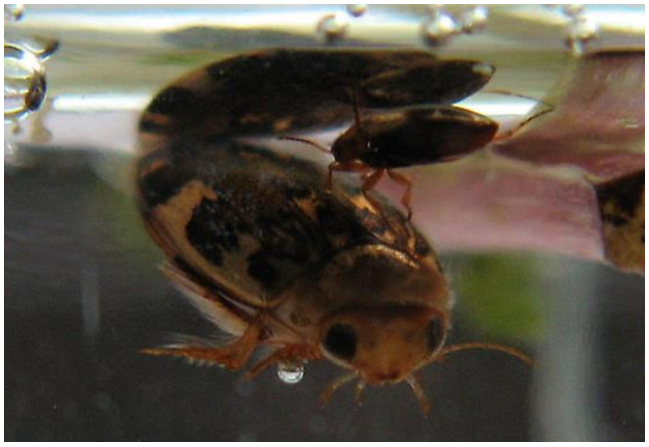

Figure 55. ***Liodessus*** adult; ***L. cantralli*** lives in moss mats of fens. Photo © Stephen Luk through BugGuide non-commercial use, with permission.

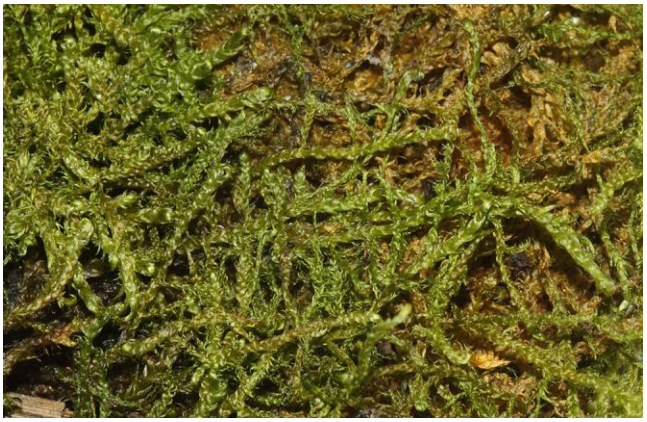

Figure 56. ***Drepanocladus aduncus***, home of ***Liodessus cantralli*** in North America. Photo from Dale A. Zimmerman Herbarium, Western New Mexico University.

Summary

Coleoptera can live in the water as larvae and as adults, but the pupae are generally on land. The aquatic adults gain oxygen by using a **plastron**, accumulating air under the forewings, or from an anal bubble. Some live on the surface and may crawl over plants such as ***Ricciocarpos natans***. Smaller beetles live among mosses in streams. But the greatest number of aquatic bryophyte associations for beetles occurs in bogs and fens.

The order **Coleoptera** (beetles) has two sub orders: **Adephaga** and **Polyphaga**. In the **Adephaga** the families **Carabidae**, **Gyrinidae**, **Haliplidae**, **Hygrobiidae**, and **Dytiscidae**. The **Dytiscidae** are especially common and diverse in bog pools and this is the only family of **Adephaga** frequently associated with bryophytes.

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