Chapter 6
Invertebrates of Irish Turloughs

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Introduction to Turloughs

Although turloughs are a recognized European habitat (CEC 2007; NPWS 2013b), almost all identified turloughs occur in Ireland, and the name is an Irish word usually interpreted to mean "dry lake." Published definitions of turloughs differ somewhat, depending on the focus or emphasis of study—geology, hydrology, botany, zoology or even terrestrial agriculture. One such, responding to the EU Water Framework Directive (EC 2000), is "groundwater-dependent terrestrial ecosystems" (Naughton et al. 2012; Kimberley and Coxon 2013).

Limnologically, turloughs are temporary freshwater bodies that form in topographic depressions in karstified limestone, filling from subterranean streams in response to localized rainfall and emptying, partly or completely, to groundwater conduits. The substrate and variable filling pattern of turloughs differentiates them from other forms of temporary waterbody. Figure 6.1 is a schematic diagram of the water budget of turloughs. It indicates that in addition to the main water inputs from groundwater, there may be small additional amounts from precipitation and overland flow. Surface streams may or may not be present. Water is lost by evapotranspiration as well as through sinks into the underlying karst. The extent and duration of flooding depends on seasonality, local weather conditions, and water table. The substrate in a turlough is usually limestone rock or thin soil, sometimes peaty, helping to retain water.

Karstification of limestone was most active in warm or tropical geological periods when sea-level was lower than that at present, and this resulted in development of tunnels and caves within the rock through the action of percolating acidic rainwater, in which streams flow or once flowed. Karstified limestone underlies some 40 % of Ireland. Later erosion and cave collapse has led to their exposure at different levels, streams sometimes meeting the surface as springs, resurgences or sinks. Irish

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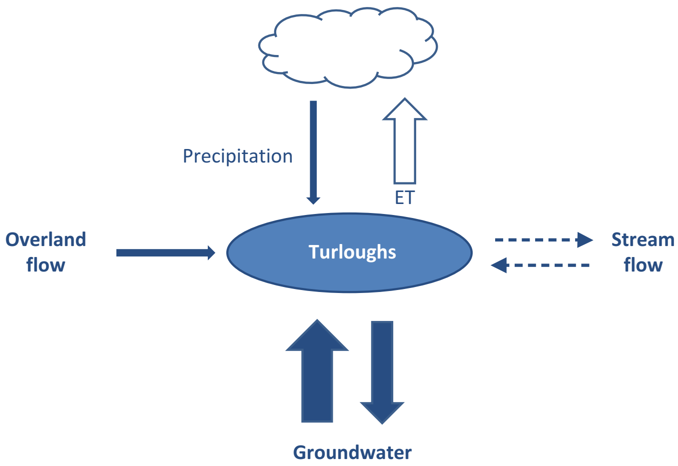

Fig. 6.1 Schematic of turlough water budgets

turloughs apparently all lie within the zone formerly affected by the last glaciation, which stripped off rocks and soil to leave exposed limestone strata.

Even if hydrology and geomorphology are suitable, with a history of glacial erosion, turloughs only develop when climatic conditions permit and rainfall exceeds evapotranspiration for at least part of the year (Fig. 6.1). In Ireland's oceanic climate, turloughs may fill and empty at any time of the year, but aquatic phases are generally found in winter and are therefore cool water, while terrestrial phases tend to occur in the drier, warmer months (Reynolds et al. 2004). Some turloughs at or near sea-level have a lunar tidal pattern influenced by tidal pressure through rock conduits, superimposed on seasonality (Reynolds 2000).

Turloughs are largely confined to the western third of Ireland, from Sligo to Kilkenny and Limerick (Coxon 1987; Goodwillie 1992), but occur most commonly in Mayo, Galway, and Clare, where deep strata of karstified Carboniferous limestone occur in lowlands (NPWS 2013b). However, turlough-like waterbodies have occasionally been described from elsewhere where the environmental conditions are right, with one (Pant-y-llyn) known from Wales (Campbell et al. 1992; Blackstock et al. 1993). Others, such as poljes, large glacial hollows that may or may not flood on an annual basis, and dolines, deep, often funnel-shaped sinkholes, whose extreme manifestations are called "tiankengs," occur in warmer climates (Gunn 2006). Similar karstic wetlands have been described in Slovenia, e.g., the intermittently filling Lake Cerknica (26 km^2) (Kranjc 2006), eastern Spain (Garcia-Gil et al. 1992; Boix et al. 2001), in North America from Mexico to eastern Canada (Coté et al. 1990), and also in China and Australia (Waltham 2006). However, turloughs differ markedly from these other geomorphological features (Coxon 1987; Naughton et al. 2012), and the faunal affinities of Irish turloughs are more northern than Mediterranean or further afield.

A complex waterbody usually referred to as a turlough is Rahasane (220 ha) in County Galway, atypical in that it fills from the adjacent Dunkellin River in flood. The anostracan *Tanymastix stagnalis* has been recorded here (Young 1975, 1976) and in adjacent temporary grassland pools, probably its more typical habitat. The species occurs sporadically in Europe, but is more commonly encountered in Mediterranean regions, and it has not been re-found in recent years in Ireland (Sheehy Skeffington et al. 2006).

In Ireland, temporary "winter-lakes" on flooded grassland show some similarities with turloughs and have been studied with them, principally by Grainger (1966, 1976, 1979), Ali et al. (1987), and Grainger and Holmes (1989). While these Irish habitats differ from turloughs in that they are not groundwater-fed, they have in common a cool-water, winter-filling periodicity and show similarities with Nordic temporary pools on Ordovician limestone Alvar grassland (e.g., Rosén 2006). The first unequivocal Irish record of the calanoid copepod *Diaptomus castor*, previously confused with the widespread planktonic *D. gracilis*, was made by Grainger (1966) in winter-flooded grassland in Mayo. *D. castor* and *D. gracilis* also often occur in turloughs.

Zonation of peripheral turlough vegetation has long been noted (Praeger 1932; Ivimey-Cook and Proctor 1966; Proctor 2010). Most turloughs fill in autumn or early winter. In the aquatic phase, turlough vegetation is limited and mostly annual, but there may also be some perennials in residual water in sinkholes (e.g., *Elodea canadensis*, *Ceratophyllum demersum*), or aquatic mosses resistant to desiccation, such as *Cinclidotus fontinaloides* (Reynolds 2000). Vascular plants of wetlands such as *Persicaria amphibia*, *Mentha aquatica,* and *Potentilla anserina* (e.g., Scannell and Webb 1983; CEC 2007; NPWS 2013a; Reynolds 2014), or the turlough form of *Ranunculus repens*, with finely divided leaves (Lynn and Waldren 2003) are also frequent. Such plants are also characteristic of river floodplains or the drawdown zone of lakes.

As water levels decline, generally in early summer, the substrate becomes exposed and starts to dry. Sparse swards of wetland annual plants are first to appear, although some perennial marsh vegetation such as *Carex nigra* (Williams and Gormally 2009) or reedbeds may persist in parts of the basin where the bottom is sealed by peat or clay (Goodwillie 2003). Depending on time and period of exposure, the terrestrial phase may come to resemble damp limestone grassland, although late-draining turloughs may be dominated by an annual *Chenopodion rubri* community (NPWS 2013b).

Invertebrate Assemblages in Turloughs

Numerous authors have written on turlough invertebrates and their ecology, but as for many other ecosystems and communities in Ireland, research activity on turloughs has been sporadic rather than sustained. Early surveys of Burren vegetation, including turloughs, were carried out by Praeger (1932) and

Ivimey-Cook and Proctor (1966), while Scannell and Webb (1983) and others considered plant distribution and phytosociology, including a seminal report to the NPWS by Goodwillie (1992) identifying and categorizing the larger turloughs in Ireland. Hydrological and geomorphological studies included Coxon (1987) and Drew (1990). These works have been well reviewed, e.g., by Goodwillie (2003).

Turloughs and their invertebrates have been reviewed from different aspects, by Reynolds et al. (1998), Reynolds (2003), Goodwillie and Reynolds (2003), O'Connor et al. (2004), Sheehy Skeffington et al. (2006), Sheehy Skeffington and Gormally (2007), Williams and Gormally (2009), and Porst and Irvine (2009a, b). Some studies reflect an interest in the Carboniferous limestone massif of the Burren and its biodiversity, while others have concentrated on specific taxa or communities. Apart from some pioneering invertebrate studies (Lansbury 1965; Grainger 1976; Donaldson et al. 1979), aquatic and terrestrial invertebrates have been less completely studied than has geomorphology and vegetation.

The best-known of turlough invertebrates are the crustaceans, including over 40 cladocerans and 6 copepods, also gastropod molluscs and certain insect groups including 58 aquatic coleopterans, 25 heteropterans, and 9 odonates (Appendix). Some invertebrate groups found in turloughs have not been investigated, such as the rotifers, nematodes and tardigrades, and the oligochaetes and dipterans of turloughs are, in general, poorly studied. The terrestrial invertebrate fauna has also been neglected. Both aquatic and terrestrial turlough invertebrate assemblages are addressed in this chapter.

Various methods have been used for sampling turlough invertebrates. Sweeping, beating, and pitfall traps are all used for collecting terrestrial phases, while in the aquatic phase dragging a plankton net or sweeping with a benthic net is common (e.g., Porst and Irvine 2009a, b). However a box enclosure method was found to yield more representative samples of the littoral-benthic fauna than use of a sweep net (O'Connor et al. 2004).

Case Studies of Turlough Invertebrates

The following case studies summarize some of the major faunistic findings on invertebrates from turloughs. Appendix lists most taxa recorded from these habitats.

Invertebrates of Burren and Aran Islands Turloughs

Turloughs in the limestone Burren hills of Counties Clare and Galway have received considerable study of their invertebrates. Donaldson et al. (1979) listed the molluscs of three Burren turloughs, and a sustained study of aquatic snails (Byrne 1981), particularly of two *Lymnaea* spp., showed very slow growth in these oligotrophic waters (Byrne et al. 1989). Since then, there appears to be some confusion about the identity of the lymnaeids *L. palustris* and *L. fusca* in turloughs. Tattersfield (1998) summarized work on wetland molluscs from Aran Islands sites, listing 23 wetland species from a total of 34 mollusc species. Through ordination Tattersfield derived a turlough group of molluscs of which *Lymnaea peregra* and *Anisus leucostoma* are most characteristic.

The characteristic microcrustaceans in Burren turloughs have been documented (Reynolds 1982, 1985b) while Duigan (1992) and Duigan and Kovach (1991) published detailed distributional surveys of chydorids in Ireland, including some turloughs. Among typical turlough species is the large chydorid cladoceran *Eurycercus glacialis* of northern and arctic regions, first discovered in Ireland by Duigan (Duigan and Frey 1987a, b) and later in Scotland; its Irish range and ecological requirements were further studied by Reynolds and Marnell (1999).

Byrne (1981) also investigated ephemeropterans and some other insect groups of turloughs, and Lansbury (1965) recorded the heteropterans *Sigara lateralis, S. dorsalis* and *Gerris lacustris* from Burren turlough habitats. In total, Lansbury (1965) and Reynolds (1985a) recorded 29 invertebrate taxa from turloughs and other karstic habitats on the Aran Islands, showing many similarities with the mainland Burren, but with reduced species richness. A maximum of 11 taxa was recorded from turlough sites, compared with four in groundwater-fed wells. *Gammarus duebeni* was found in several habitats, suggesting it may penetrate through fissures in the limestone (Reynolds 1985a).

Gort Turlough Flooding

Following several exceptional and prolonged flooding episodes in the 1990s of a series of turloughs lying in the lowlands north of Gort, County Galway and ranging in size up to 290 ha, a project was initiated to look into causes and remedial action (Southern Water Global 1996, 1997; Tynan et al. 2002). While most attention was paid to hydrology, defining and delimiting the tracks of subterranean waters discharging into Galway Bay, Reynolds (2000) characterized the different turloughs and summarized the characteristic invertebrate fauna of 15 turlough-associated sites, grouped into five districts by their hydrology and apparent drainage relationships. Districts yielded between 36 (eastern sites) and 81 (northern sites) taxa. Species occurring in all five districts included the microcrustaceans *Daphnia pulex, Simocephalus vetulus, Chydorus sphaericus, Polyphemus pediculus, Cyclops agilis* and *Candona candida*, and the macroinvertebrates *Polycelis nigra, Bithynia tentaculata* and *Lymnaea peregra (=Radix balthica)*. The characteristic species *Eurycercus lamellatus, Diaptomus castor* and *Planorbis (Gyraulus) laevis* were not recorded in eastern sites, while *Eurycercus glacialis* was found only in western and southern turloughs. Bond (1997) listed over 240 lepidopterans from the area, relatively few of which had strong turlough links, including *Bactra furfurana, Deltote uncula*, and the scarce *Paraponyx stratiotata*.

Terrestrial Invertebrates of Turloughs

Pioneering work by Speight (1976, 1977) identified carabids and other beetles in the terrestrial phase of turloughs. More recently, Lott and Foster (1990) recorded terrestrial beetles from wetland sites, including turloughs, and insects of the grasslands associated with turloughs have received attention from Good and Butler (2001) and Good (2004). Hydrology and terrestrial phase insect communities have been the focus of attention in a series of studies (Moran et al. 2003, 2008, 2011; Ní Bhriain et al. 2002, 2003; Sheehy Skeffington and Gormally 2007; Williams et al. 2010). Moran et al. (2011) working on the 28 ha Skealogan turlough, designated a Special Area of Protection, studied a *Cirsio-Molinietum* community flooded for approximately three months in the year, and a more aquatic *Ranunculo-Potentillietum anserinae* sward, flooded for about 6 months, and summarized the carabid findings from the two plant communities. *Bembidion aeneum* and *Agonum muelleri* are characteristic carabids of short-duration flooded, grazed swards, with *Nebria brevicollis* and *Chlaenius nigricornis* representative of grazed swards undergoing longer duration flooding. Turlough species survive flooding by their short life cycle, ability to fly, and early breeding followed by hibernation; species of wetter areas tend to be larger.

Williams et al. (2009, 2010) studied the marsh flies (Diptera: Sciomyzidae) of this and other turloughs. They found a fauna of seven species, 91 % dominated by *Ilione albiseta* and other univoltine species, and that microhabitat conditions were important in their survival. Univoltine species with aquatic larvae preyed on pulmonates or bivalves; others survived on damp surfaces, or were fully terrestrial. Most of the group seem to track hydrological regimes and plant communities rather than favoring habitat heterogeneity. In a related study, Williams and Gormally (2009) looked at the role of environmental gradients in turloughs on terrestrial, aquatic, and semiaquatic molluscs.

Ecology and Natural History of Turlough Invertebrates

Aquatic Invertebrates

Aquatic invertebrates of turloughs fall into two groupings; planktonic or semiplanktonic forms (mainly microcrustaceans and dipteran larvae), and littoral-benthic forms, predominantly insects, but also many crustaceans, molluscans, and annelids. In turloughs, development of aquatic invertebrate communities is controlled by a specific range of limnological, chemical, and ecological factors. Whether planktonic or littoral-benthic, aquatic turlough invertebrates experience a suite of often harsh environmental conditions. The schematic in Fig. 6.2 summarizes the influence of some major factors on the aquatic biota of turloughs, with the importance of each factor explained below.

Limnological Controls

Clearly, important limnological factors to turlough invertebrates include hydrography, periodicity of aquatic phase, timing of exposure, and water temperature. Water in turloughs is usually temporary or periodic, most often present in cooler winter months (see Fig. 6.2). As such, the aquatic communities that develop are typically dominated by short-lived taxa, often adapted to cool water such as chydorid and daphniid microcrustaceans and some insect larvae (e.g., *Cloeon dipterum*). The large chydorid microcrustacean *Eurycercus glacialis* (Duigan and Frey 1987a, b), mentioned above, is cold adapted.

Hydroperiod will determine the communities that can develop; short hydroperiods tend to limit longer-lived predators, but too brief flooding may lead to the loss of species before they reach maturity. Turlough aquatic invertebrates must survive periods of desiccation, chiefly in summer, by behavioral or life-history adaptations (e.g., resistant resting stages such as cladoceran ephippia, or terrestrial stages in insects). Drying out in cold seasons can also kill desiccation-resistant resting stages. Because the aquatic phase is unpredictable in its timing and length, the aquatic invertebrate fauna of turloughs is restricted, and may have to recolonize actively or passively (Reynolds et al. 2004; O'Connor, personal communication 2014).

Some longer-lived site-faithful species, such as lymnaeid snails, *Gammarus duebeni* and odonate larvae, may survive dry phases in groundwater or small pools, in mud, or under a felt of drying vegetation. Although most insect colonizers of turloughs are ready flyers, brachypterous or apterous forms, for example among corixids, must be able to survive dry periods in situ (Tobin and McCarthy 2004).

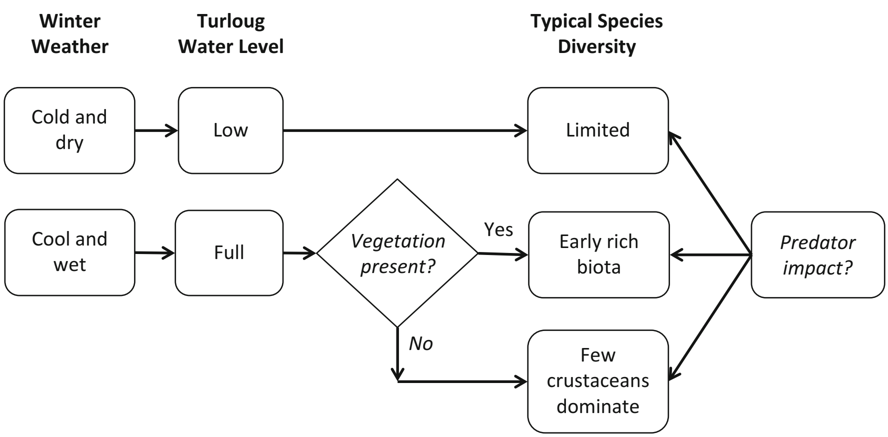

Fig. 6.2 Factors influencing aquatic phase biodiversity

The plankton is chiefly affected by limnological factors such as water movement, depth, area, fetch, and exposure, sometimes causing plankters to drift onshore with risks of stranding. However, the same factors at the correct time can place resting stages such as crustacean ephippia on the shoreline until the next major aquatic period. Active or passive dispersal of temporary or isolated pond macroinvertebrates is of wide interest, with a general review by Bilton et al. (2001a, b) and more specific zooplankton studies by, among others, Louette and De Meester (2005).

Turlough water chemistry is less variable than among many other types of waterbodies, being dominated by calcium and carbonate-based chemistry. However, the considerable variation in nutrient level in turloughs, from ultra-oligotrophic to eutrophic, affects productivity. Dissolved oxygen levels are also important but rarely limiting, except under eutrophic summer-flooding conditions, when algal blooms may decay leading to oxygen deficiency.

Biotic Controls

An important ecological factor for aquatic invertebrates is habitat complexity. Some complexity relates to the presence of irregularities in the turlough basin, where water and aquatic forms may be retained in sinkholes or in marshes. But complexity more often relates to biotic interactions with plants, competitors, and predators.

Microhabitat complexity is primarily related to the presence or absence of vegetation, and its degree or fineness of branching (Eitam et al. 2004). Periphyton grows on plant surfaces, which is food for insect and crustacean grazers, and refuge from predation. Leaves of the turlough form of *Ranunculus repens* and of the ubiquitous *Potentilla anserina* are both finely divided.

Available food webs are initially detritus-based and are quickly exploited by microcrustaceans and insect larvae. Aquatic invertebrate communities are then structured by competition, e.g., between early chydorid colonists for effective dominance (Reynolds et al. 2004), and by predation; both factors result in distinctive faunal species lists and specialist taxa.

Spencer et al. (1999) showed that larger pools tend to have higher proportions of predators, and Bilton et al. (2001a, b) suggested the pattern was due primarily to water permanence. In turloughs invertebrate predators are typically sparse and may be amphibious (such as diving spiders *Argyroneta aquatica*) or able to fly as adults (Coleoptera, Hemiptera, Odonata). Among planktonic predators, *Polyphemus pediculus* is found in many lowland turloughs, where the copepod *Cyclops scutifer* may also be common (Reynolds 2000, 2003). Fish, however, are rarely present in turloughs (Williams et al. 2006), allowing the larger planktonic cladocerans to thrive (Reynolds 1985b; Reynolds and Marnell 1999).

Terrestrial Invertebrates

In their terrestrial phase invertebrate communities of turloughs are structured by physical factors and microclimate, including temperature and desiccation, and by ecological factors (Regan 2005) such as timing of vegetation cover and prevalence of predators. The schematic in Fig. 6.3 indicates how spring weather (wet or dry, early or late), habitat complexity, and presence of predators affects terrestrial phase biodiversity.

As turloughs dry out, insect larvae that survived submergence (e.g., some Coleoptera and Diptera) contribute as adults to a suite of grassland terrestrial detritivores. Chief among terrestrial insect predators are heteropterans and a broad suite of staphylinids (Good 2004), carabids (Moran et al. 2011) and specialized mollusc predators such as sciomyzid fly larvae, which may be terrestrial or aquatic (Ryder et al. 2003; Williams et al. 2009, 2010); others include spiders and mites. These may be controlled by habitat complexity (some turloughs retain patches of standing water or marsh) and by levels of management such as grazing pressure and trampling (Moran et al. 2008, 2011; Ní Bhriain et al. 2002, 2003; Regan 2005; Regan and Moran 2005).

Different plant communities support a characteristic carabid community, e.g., the *Cirsio-Molinietum* community (short duration of flooding), with 9 carabid species in ungrazed habitats, 7 in grazed; and the *Ranunculo-Potentilletum anserinae* community (long duration of flooding), with 10 carabid species in ungrazed and 7 in grazed habitats. Carabids of turloughs are detailed in Moran et al. (2011), arranged by their plant community and indicator importance.

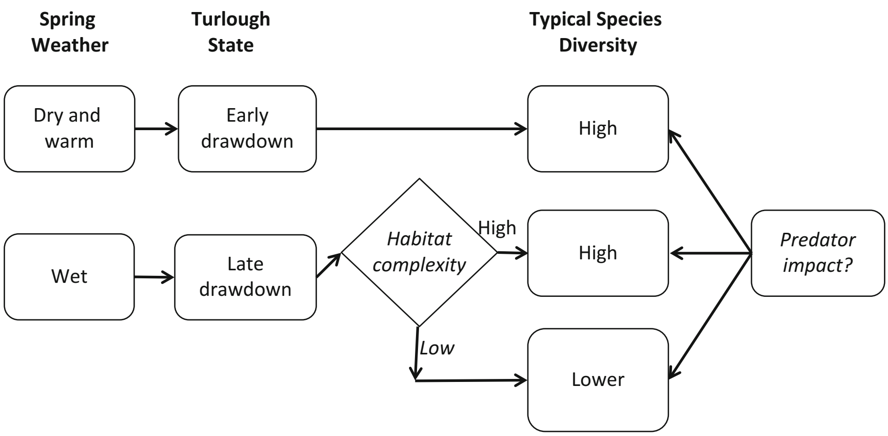

Fig. 6.3 Three main factors influencing terrestrial phase biodiversity

Turlough Invertebrates: Management and Conservation Issues

Turloughs are not uniform, and their management must depend on the primary issues affecting each and their relative importance, having due regard for the livelihood of land owners. Turlough water levels may rise rapidly following local rainfall, e.g., a rise of up to 8 m in 24 h is known in Blackrock Turlough, Co. Galway. Excess water may then damage houses and farm buildings, and inundate roads.

There is now better understanding of the groundwater influences of turloughs and other "groundwater-dependent terrestrial ecosystems" (Tynan et al. 2007; Kimberley and Coxon 2013). County maps of groundwater vulnerability to contaminants from human activities are available (Daly and Warren 1998). Stocking with heavier breeds of cattle may result in trampling of the soil and permanent sealing of the basin, converting turloughs into ponds. Finally, the degree and timing of drying out affects turlough site biodiversity (Collinson et al. 1995; Moran et al. 2008).

Some socioeconomic issues may override conservation priorities; chief among these have been structural damage from flooding (Ní Bhroin 2008) and a growing demand for land for grazing (Ní Bhriain et al. 2002, 2003). Ryder et al. (2005) and Williams et al. (2009) discuss the implications of farmland management and grazing on terrestrial plant and dipteran communities of turloughs. Curtis et al. (2009) stress the importance of avoiding drainage of the basin while managing for good water quality (avoiding ploughing, fertilization or enrichment) and periodicity. Mitigating actions for potentially damaging flood levels, discussed in the Gort Flooding reports (Southern Water Global 1996, 1997) include provision of small moveable dams on feeder streams to hold back or divert excess inflowing water.

Some turlough conservation issues in aquatic and terrestrial phases have been outlined by Reynolds (1996) and NPWS (2013a), and consultancy reports have identified others. Turloughs are a priority habitat in the EU Habitats Directive (EEC 1992) and many turloughs are designated Special Areas of Conservation (SACs) under the Directive—some 70 turlough SACs are listed in Tynan et al. (2007), also giving their trophic sensibilities to nutrient enrichment. Others have less statutory protection, although they may contain protected species. Annex II in the EU Habitats Directive lists priority species, including three species of *Vertigo* snails and the Marsh Fritillary butterfly (*Euphydryas aurinia*); these may occur within turloughs but are not characteristic of them. No characteristic turlough species are protected in this European directive. The only invertebrates apparently limited to turlough habitats in Ireland are the crustacean *Eurycercus glacialis* and the aquatic weevil *Bagous brevis.* Both are considered rare in Ireland and their protection is important.

Biomonitoring, including with invertebrates, is a useful tool to assess turlough ecological health. A large-scale turlough project involving many specialists has been ongoing since 2005, reporting to government via the National Parks and Wildlife Service; some results have been published. Porst and Irvine (2009a, b) listed invertebrates from lowland turloughs and commented on within-turlough habitat variability; this was considered to be less than between turloughs, and Porst and Irvine (2009b) recommended that a single site sample would be an adequate metric for the aquatic community for many purposes. Porst et al. (2012) examined the turlough recolonization process after flooding, highlighting the importance of life-cycle strategies to overcome ecological disturbance. Soils and groundwater pressures were discussed by Kimberley and Coxon (2013) and Kimberley and Waldren (2012).

Water beetles are increasingly seen as useful for characterizing the conservation value of waterbodies, and some detailed surveys of beetles of limestone lakes and turloughs have been carried out. Early surveys by Bilton (1988), Lott and Foster (1990) and Bilton and Lott (1991) identified a suite of beetles associated with the mossy shores of limestone lakes and turloughs. Beetle communities were classified by Foster et al. (1992) and these mossy-edge beetles were considered sensitive to disturbance. A Red List of Irish beetles was produced (Foster et al. 2009), while additions to turlough beetle lists were provided by Bradish et al. (2002), O'Connor et al. (2004), and Reynolds (2014). The beetles *Agabus labiatus, Bagous brevis, B. limosus* and *Berosus stigmaticollis* were found to have particular strongholds in turlough habitats.

Despite an increasing body of knowledge of characteristic turlough species, there is currently no national protection for turlough invertebrates. However, Irish Red Lists, particularly those for water beetles (Foster et al. 2009) and odonates (Nelson et al. 2011) identify species largely restricted to turloughs, and describe their conservation status. It is to be hoped that with such official recognition, some endangered invertebrates of these unique waterbodies will gain appropriate protection at a national level.

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Appendix

List of turlough invertebrate taxa. Most invertebrate turlough dwellers are typical of, but not restricted to, turloughs in the wet phase (List A) or in the dry phase (List B). Where species occur in either phase, or where turloughs do not dry out completely, they have been placed in the more characteristic phase habitat. In the list, species in **bold** are typical of turloughs and considered of high conservation value (e.g., Reynolds 2000; NPWS 2007, 2013a; Porst and Irvine 2009a, b). Species in (brackets) have rarely been recorded in turloughs, and records may be erroneous.

Higher classification	Families	Genus-species	References*
A. WET PHASE			
PHYLUM CNIDARIA			
Class Hydrozoa			
Order Anthomedusae	Family Hydridae	*Chlorohydra viridissima*	1, 40
		Hydra sp.	2, 3
PHYLUM PLATY HELMINTHES			
Class Turbellaria			
Order Tricladida	Family Planariidae	*Polycelis nigra/tenuis*	1, 4, 5, 54
		Polycelis nigra	1, 3, 5, 6, 7, 40
		Polycelis sp.	2
PHYLUM ANNELIDA			
Class Oligochaeta			4, 7, 54
Class Hirudinea	Family Glossiphoniidae	*Glossiphonia complanata*	1, 3, 4, 7, 8, 40, 54
		Theromyzon tessulatum	7, 54
		Helobdella stagnalis	40
	Family Haemopidae	*(Haemopis sanguisuga)*	4, 7, 54
PHYLUM MOLLUSCA			
Class Gastropoda			
Order Mesogastropoda	Family Tateidae	*Potamopyrgus antipodarum (jenkinsii)*	1, 3, 4, 7, 53
	Family Lymnaeidae	***Galba truncatula***	1, 4, 7, 9, 52, 54
		(Lymnaea glabra)	4, 54
		Lymnaea (Stagnicola) palustris	3, 7, 8, 11, 12
		Lymnaea peregra (Radix balthica)	1, 3, 4, 7, 8, 9, 11, 40, 53, 54
		Lymnaea palustris	7
		Lymnaea fusca	52, ml
		Lymnaea stagnalis	3, 4, 13, 40
		Myxas glutinosa	4
	Family Physidae	*(Aplexa hypnorum)*	7
		Physa fontinalis	4, 7, 54
	Family Succineidae	*Oxyloma pfeifferi*	9
		Oxyloma elegans	52
		Succinea putris	3, 40, 54
		Succinea sp.	4, 7
	Family Acroloxidae	*(Acroloxus lacustris)*	40

(continued)

Higher classification	Families	Genus-species	References*
	Family Planorbidae	*Anisus leucostoma*	1, 7, 9
		Anisus vortex	40
		Bathyomphalus contortus	3, 4, 40, 54
		Gyraulus crista	4, 8, 52, 54
		Gyraulus albus	7, 40
		Gyraulus laevis	3, 40, 54
		Planorbarius corneus	54
		(Planorbis carinatus)	7
		(Planorbis planorbis)	4, 7, 40, 52
	Family Bithyniidae	***Bithynia tentaculata***	3, 7, 8, 40, 54
	Family Valvatidae	*Valvata cristata*	1, 4, 8, 52
		Valvata piscinalis	8, 40
	Family Ellobiidae	*Carychium minimum*	3
	Family Vertiginidae	*Vertigo antivertigo*	40
	Family Gastrodontidae	*Zonitoides* sp.	4, 7, 54
Class Bivalvia	Family Sphaeriidae		3, 7, 8, 54
		Pisidium obtusale	52, 53
		Pisidium personatum	53
PHYLUM ARTHROPODA			
S/PH CRUSTACEA			
Class Branchiopoda			
Order Anostraca	Family Tanymastigidae	***Tanymastix stagnalis***	14, 15, 16, 17
Order Diplostraca	Family Bosminidae	*Bosmina longirostris*	3, 18, 20, 40
	Family Chydoridae	*Acroperus harpae*	3, 18, 19, 20, 21, 40
		Acroperus elongatus	20
		Alona (Biapertura) affinis	2, 3, 5, 18, 20, 22
		Alona quadrangularis	3, 18, 19, 20, 22, 40
		Alona costata	20, 22
		Alona guttata	19, 20, 22
		Alona rectangula	3, 22, 23, 40
		Alona rustica	5, 22
		Alonella excisa	5, 18, 19, 20, 22
		Alonella exigua	22
		Alonella nana	19, 20, 22
		Alonopsis elongata	5, 22
		Anchistropus emarginatus	22
		Chydorus latus	3
		Chydorus sphaericus	2, 3, 18, 20, 22, 23, 24, 40

(continued)

Higher classification	Families	Genus-species	References*
		Disparalona rostrata	19
		Eurycercus glacialis	2, 3, 5, 18, 22, 25, 26, 40
		Eurycercus lamellatus	2, 3, 18, 20, 22, 27, 40
		Graptoleberis testudinaria	3, 18, 19, 20, 22, 40
		Lathonura rectirostris	22
		Pleuroxus aduncus	22
		Pleuroxus trigonellus	19, 20, 28
		Pleuroxus truncatus	19, 20, 22, 28
		Pleuroxus uncinatus	22
		Picripleuroxus laevis	22, 28
		Pseudochydorus globosus	22
		Rhynchotalona falcata	20
	Family Daphniidae	*Ceriodaphnia dubia*	3, 40
		Ceriodaphnia megops	3, 40
		Ceriodaphnia quadrangula	3, 20, 40
		Daphnia hyalina var lacustris	18
		Daphnia longispina	2, 3, 18, 40
		Daphnia magna	18
		Daphnia obtusa	18
		Daphnia pulex	2, 3, 18, 22, 23, 24, 40
		Daphnia sp.	2, 22
		Scapholeberis mucronata	19
		Simocephalus exospinosus	3
		Simocephalus vetulus	2, 3, 18, 20, 40
		Simocephalus sp.	22
	Family Macrothricidae	*Macrothrix* sp.	22
	Family Ilyocryptidae	*Ilyocryptus sordidus*	20
	Family Polyphemidae	***Polyphemus pediculus***	2, 3, 40
	Family Sididae	*Latona setifera*	20
		Sida crystallina	20, 22
Class Maxillopoda			
S/Cl Copepoda			
Order Harpacticoida	Family Canthocamptidae	*Canthocamptus microstaphylinus*	29
Order Calanoida	Family Diaptomidae	***Diaptomus castor***	2, 3, 5, 30, 31, 40
		Diaptomus cyaneus	16, 30
		Eudiaptomus gracilis	32, 33
		Arctodiaptomus wierzejskii	16, 30

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Higher classification	Families	Genus-species	References*
Order Cyclopoida	Family Cyclopidae	***Cyclops agilis***	2, 3, 40
		Cyclops scutifer	3, 40
S/Cl Ostracoda		Ostracoda sp.	4, 54
Order Podocopida	Family Candonidae	***Candona candida***	3, 40
	Family Cyprididae	*Cypris puber*	32, 33
Class Malacostraca			
Order Amphipoda	Family Gammaridae	*Gammarus duebeni*	1, 2, 3, 7, 20, 27, 40
		Gammarus lacustris	4, 7, 40, 54
	Family Niphargidae	*Niphargus kochianus irlandicus*	34, 35
Order Isopoda	Family Asellidae	*Asellus aquaticus*	3, 4, 7, 54
		Asellus meridianus	1, 4, 7
		Asellus sp.	3, 40
S/PH CHELICERATA			
Class Arachnida			
S/Cl Acari			4, 7, 54
Order Trombidiformes	Family Hydrodromidae	*Hydrodroma* sp.	3
	Family Pionidae	*Piona conglobata*	3
	Family Unionicolidae	*Unionicola crassipes*	3
Order Araneae	Family Cybaeidae	*Argyroneta aquatica*	2, 4, 54
S/PH HEXAPODA			
Class Insecta			
Order Ephemeroptera	Family Baetidae	***Cloeon dipterum***	3, 4, 7, 36, 40, 54
		Cloeon simile	4, 7, 12, 54
	Family Leptophlebiidae	*Leptophlebia vespertina*	4
	Family Caenidae	*Caenis horaria*	4
	Family Siphlonuridae	*Siphlonurus alternatus (linneanus)*	3, 36, 40
		Siphlonurus armatus	36
Order Odonata	Family Lestidae	***Lestes dryas***	4, 5, 37, 54
		Lestes sponsa	54
		Lestes sp.	4, 54
	Family Coenagrionidae	*Pyrrhosoma nymphula*	13
		Coenagrion pulchellum/ puella	54
		Coenagrion sp.	8, 10, 54
		Ishnura elegans	13, 54
	Family Calopterygidae	*Calopteryx splendens*	13

(continued)

Higher classification	Families	Genus-species	References*
	Family Libellulidae	***Sympetrum sanguineum***	4, 5, 13, 37, 54
		Sympetrum striolatum	13
		Libellula quadrimaculata	1
Order Plecoptera	Family Nemouridae	*Nemoura cinerea*	3, 4, 40
Order Trichoptera	Family Limnephilidae	*Grammotaulius nigropunctatus*	7
		Limnephilus auricula	4, 7, 54
		Limnephilus affinus/incisus	7, 40
		Limnephilus binotatus	7
		Limnephilus centralis	4, 54
		(Limnephilus decipiens)	7, 54
		Limnephilus flavicornis	7, 40
		Limnephilus lunatus	4, 54
		Limnephilus marmoratus	4, 54
		Limnephilus rhombicus	7
		Limnephilus vittatus	7
		Limnephilus sp.	40
	Family Leptoceridae	*Mystacides longicornis*	8, 54
		Phagopteryx brevipennis	4
		Triaenodes bicolor	54
Order Hemiptera	Family Corixidae	*Arctocorisa germari*	7
		Callicorixa praeusta	7, 38, 39, 40, 54
		Corixa affinis	1, 38
		Corixa panzeri	7
		Corixa punctata/iberica	4, 38, 54
		Corixa wollastoni	40
		Cymatia bonsdorffi	39
		Hesperocorixa castanea	38, 39
		Hesperocorixa linnei	39, 54
		Hesperocorixa sahlbergi	39, 54
		Sigara concinna	1, 7, 39, 40
		Sigara dorsalis	1, 7, 39
		Sigara falleni	4, 7, 39, 40
		Sigara lateralis	7, 39, 40
		(Sigara scotti)	7, 40
	Family Gerridae	*Gerris lacustris*	3, 40, 41
		Gerris argentatus	40
		Gerris lateralis	1, 3
		Gerris costai	1
	Family Notonectidae	*Notonecta glauca*	4, 7, 40, 54
	Family Veliidae	*Microvelia reticulata*	7
		Velia caprai	1
	Family Nepidae	*(Nepa cinerea)*	7
	Family Saldidae	*Saldula opacula*	5
		Saldula saltatoria	41

(continued)

Higher classification	Families	Genus-species	References*
Order Coleoptera	Family Chrysomelidae		4, 54
		Donacia clavipes	41
		Donacia sp.	4
		Galerucella lineola	41
		Platyeumaris sericea	41
	Family Curculionidae		4, 54
		Bagous brevis	5, 42
		Bagous limosus	5, 42
	Family Dryopidae	*Dryops luridus*	43
		Dryops similaris	5, 55
		Dryops sp.	4, 7, 54
	Family Dytiscidae	*Agabus bipustulatus*	1, 4, 7
		Agabus labiatus	4, 5, 7, 40, 42, 43, 54
		(Agabus melanocornis)	7
		Agabus nebulosus	4, 5, 7, 40, 43, 54
		Agabus sp.	3, 4, 54
		Colymbetes fuscus	7, 54
		(Dytiscus circumcinctus)	7
		(Dytiscus sulcatus)	7
		Dytiscus sp.	4, 54
		Graptodytes bilineatus	4, 5, 7, 40, 54, 55
		Graptodytes granularis	40
		Hydaticus sp.	4, 54
		Hydroporus erythrocephalus	4, 7, 40, 54
		(Hydroporus memnonius)	7
		Hydroporus palustris	1, 4, 7, 40, 54
		(Hydroporus pubescens)	4, 54
		Hygrotus inaequalis	4, 7, 54
		Hygrotus impressopunctatus	4, 5, 7, 54, 55
		Hygrotus quinquelineatus	4, 7, 54, 55
		Hygrotus sp. larvae	4
		Hyphydrus ovalis	54
		(Ilybius fuliginosus)	7
		Ilybius sp.	4, 54
		Laccophilus minutus	4, 54
		Laccophilus sp.	4
		Porhydrus lineatus	7, 40, 54
		Porhydrus sp.	40
		Rhantus exsoletus	4, 54
		Rhantus frontalis	5, 43, 54
		Rhantus sp.	4, 54
		(Suphrodytes dorsalis)	7

(continued)

Higher classification	Families	Genus-species	References*
	Family Hygrobiidae	*(Hygrobia hermanni)*	7, 54
	Family Elmidae	*Oulimnius sp.*	54
	Family Haliplidae	*Haliplus confinis*	1, 7, 40
		Haliplus fulvus	4, 7
		Haliplus inaequalis	40
		Haliplus lineolatus	40
		Haliplus lineatocollis	7
		Haliplus obliquus	5
		Haliplus ruficollis group	7, 54
		Haliplus 15-lineatus	40
		Haliplus variegatus	5, 7
		Haliplus sp.	4, 40, 54
	Family Helophoridae	*Helophorus aequalis*	43
		Helophorus brevipalpis	1, 4, 7, 43, 54
		Helophorus grandis	7, 43
		Helophorus minutus	5
		Helophorus nanus	5
		Helophorus obscurus	1
		Helophorus sp.	3, 54
	Family Noteridae	*Noterus clavicornis*	54
	Family Hydraenidae	*Ochthebius minimus*	43
		Ochthebius dilatatus	4, 5, 7, 43, 54
		(Ochthebius nilssoni)	44
	Family Hydrophilidae	***Berosus signaticollis***	4, 5, 7, 42, 54, 55
		(Cercyon tristis)	4
		(Hydrobius fuscipes)	1, 4
		Laccobius biguttatus	54
		Laccobius colon	5
		Laccobius minutus	5
	Family Carabidae	*Agonum afrum*	45
		Agonum marginatum	45
		Agonum piceum	5, 45
		Bembidion clarkii agg.	45
		Blethisa multipunctata	5, 45, 46
		Carabus granulatus	45
		Chlaenius nigricornis	5, 45
		Dyschirius globosus	45
		Elaphrus cupreus	45
		Loricera pilicornis	45
		Nebria brevicollis	45
		Pelophila borealis	5, 45, 46
		Pterostichus gracilis	45
		Pterostichus minor	45
	Family Staphylinidae	*Carpelimus impressus*	47
		Philonthus furcifer	5
		Stenus Kiesenwetteri	47

(continued)

Higher classification	Families	Genus-species	References*
Order Diptera	Family Ceratopogonidae		4, 54
	Family Chironomidae		8, 10, 54
		Calopsectra sp.	8
		Cladotanytarsus sp.	8
		Dicrotendipes sp.	8
		Micropsectra sp.	8
		Parachironomus sp.	8
		Paratanytarsus sp.	8
		Phaenopsectra sp.	8
		Polypedilum sp.	8
		Tanypus sp.	8
	Family Culicidae		4, 54
	Family Psychodidae		4, 54
	Family Sciomyzidae	*Colobaea distincta*	5
		Hydromya dorsalis	10
		Ilione albiceta	5, 10, 48, 49
		Ilione lineata	10, 48
		Limnia unguicornis	48
		Pherbellia nana	5, 48
		Pherbina coryleti	5, 10, 48
		Pherbina schoenherri	10
		Sepedon spinipes	10
		Sepedon sphegea	10
		Tetanocera arrogans	10, 48
		Tetanocera hyalipennis	10
		Tetanocera elata	48
		Tetanocera sp.	10
	Family Stratiomyidae		4
	Family Tabanidae		4
	Family Tipulidae		4, 54
Order Lepidoptera	Family Pyralidae	*Acentropus niveus*	8
B: DRY PHASE			
PHYLUM ANNELIDA			
Order Oligochaeta			4
PHYLUM MOLLUSCA			
Class Gastropoda	Family Gastrodontidae	*Zonitoides* sp.	4, 7
	Family Ellobiidae	***Carychium minimum***	3, 52
	Family Valloniidae	*Vallonia pulchella*	52
	Family Agriolimacidae	*Deroceras laeve*	52

(continued)

Higher classification	Families	Genus-species	References*
PHYLUM ARTHROPODA			
Class Insecta			
Order Orthoptera	Family Tetrigidae	*Tetrix subulata*	5, 41
		Tetrix undulata	41
	Family Acrididae	*Chorthippus albomarginatus*	5
Order Hemiptera	Family Saldidae	*Saldula opacula*	5
Order Coleoptera	Family Chrysomelidae		4
		Donacia sp.	4
	Family Curculionidae		4
		Bagous brevis	5, 42
		Bagous limosus	5, 42
	Family Dryopidae	*Dryops* sp. larvae	4
		Dryops similaris	5
	Family Carabidae	*Agonum marginatum*	45
		(Agonum gracile)	45
		Agonum muelleri	5, 45
		Agonum livens	46
		Agonum lugens	5, 46
		Agonum piceum	5, 45
		Agonum viduum	45, 56
		(Agonum thoreyi)	45
		(Acupalpus consputus)	45
		(Amara communis)	45
		(Amara similata)	45
		(Anisodactylus binotatus)	45
		Badister anomalus	47
		Badister meridionalis	5, 46
		Badister peltatus	5, 45
		Bembidion aeneum	5, 45
		Bembidion clarkii	5, 45
		Bembidion doris	45, 56
		Bembidion gutulla	45
		(Bembidion lampros)	45
		(Bembidion mannerheimii)	45
		(Bembidion tetracolum)	45
		Blethisa multipunctata	5, 45, 46, 56
		Carabus granulatus	5, 45
		Chlaenius nigricornis	5, 45
		(Clivina fossor)	45
		Dyschirius globosus	45, 56
		Dyschirius luedersi	45, 56
		Elaphrus cupreus	45, 56

(continued)

Higher classification	Families	Genus-species	References*
		(Harpalus rufipes)	45
		Loricera pilicornis	5, 45, 56
		Pelophila borealis	5, 45, 46
		Platynus livens	5
		(Platynus dorsale)	45
		(Pterostichus anthracinus)	45
		(Pterostichus crenatus)	45
		(Pterostichus versicolor)	45
		Pterostichus diligens	45
		Pterostichus minor	45
		Pterostichus melanarius	45
		Pterostichus niger	45
		Pterostichus nigrita	5, 45
		Pterostichus strenuus	45
		(Stenolophus mixtus)	45
	Family Staphylinidae	*Philonthus furcifer*	5
		Philonthus quisquiliarius	56
		Atheta elongatula	56
		Atheta graminicola	56
		Atheta hygrotopora	56
		Atheta melanocera	56
		Carpelimus rivularis	56
		Gnypeta carbonaria	56
		Stenus binotatus	56
		Stenus boops	56
		Stenus fuscipes	56
		Stenus juno	56
		Stenus umbratilus	56
		Tachyusa atra	56
	Family Silphidae	*Thanatophilus dispar*	5
Order Diptera	Family Sciomyzidae	*Colobaea distincta*	5, 49
		Ilione albiceta	5, 48
		Ilione lineata	48
		Limnia unguicornis	48
		Pherbellia nana	5, 48
		Pherbina coryleti	5, 48
		Tetanocera arrogans	48
		Tetanocera elata	48
	Family Stratiomyidae	*Odontomyia angulata*	50
Order Lepidoptera	Family Glyphipterigidae	*Odontognophos dumentata*	bn
	Family Gelechiidae	*Monochroa lutulentella*	5
	Family Crambidae	*Paraponyx stratiotata*	5, 57

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Higher classification	Families	Genus-species	References*
	Family Pyralidae	*Acentrotus niveus*	8, 10
		Acentria ephemerella	54
	Family Noctuidae	*Deltote uncula*	5, 57
	Family Pieridae	*Gonepteryx rhamni*	51
	Family Nymphalidae	*Anthocharis cardamines*	51
		Hipparchia semele	51
	Family Tortricidae	*Bactra furfurana*	5, 57

*1. Reynolds (1985a); 2. Reynolds and Marnell (1999); 3. Reynolds (2000); 4. Porst and Irvine (2009a, b); 5. NPWS (2013a); 6. Reynolds (1996); 7. O'Connor et al. (2004); 8. Byrne and Reynolds (1982); 9. Tattersfield (1998); 10. Williams et al. (2010); 11. Byrne et al. (1989); 12. Byrne (1981); 13. Ní Bhroin (2008); 14. Young (1975); 15. Young (1976); 16. Grainger (1979); 17. Grainger (1991); 18. Reynolds et al. (2004); 19. Kane (1903); 20. Reynolds (1985b); 21. Reynolds and Marnell (1999); 22. Duigan (1989); 23. Duigan (1988); 24. Duigan (1987); 25. Duigan and Frey (1987a); 26. Duigan and Frey (1987b); 27. Reynolds (1982); 28. Duigan (1992); 29. O'Connor and Holmes (1990); 30. Ali et al. (1987); 31. Grainger (1966); 32. Grainger in Reynolds (1996); 33. Reynolds et al. (1998); 34. Hazelton (1974); 35. Knight and Penk (2010); 36. Kelly-Quinn and Regan (2012); 37. Nelson et al. (2011); 38. Tully et al. (1991); 39. Tobin and McCarthy (2004); 40. Reynolds (2003); 41. Morris (1966/1967); 42. Foster et al. (2009); 43. Reynolds (2014); 44. O'Callaghan et al. (2009); 45. Moran et al. (2011); 46. CEC (2007); 47. Owen (1994); 48. Williams et al. (2009); 49. Ryder et al. (2003); 50. Gittings (2007); 51. Nash et al. (2012); 52. Williams and Gormally (2009); 53. Tattersfield (1998); 54. Porst and Irvine (2009a, b); 55. Bilton (1988); 56. Lott and Foster (1990); 57. Bond (1997); bn. B. Nelson personal communication (2014); ml. M. Long personal communication (2015).

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