NOTES ON FORMATION AND LIFE OF PONDS OF THE FALKLAND ISLANDS AND SOUTH GEORGIA

By MILTON W. WELLER*

ABSTRACT. Ponds of the Falkland Islands and South Georgia were examined for location, structure, submergent plants, pH and invertebrate populations. Although most are formed by usual geological processes, ponds located in peat in both areas appear to have formed by solifluction. Such ponds in peat were of uniform depth, highly acid, and of low productivity of plants and invertebrates. A possible explanation for the formation of these ponds on ridges and slopes is given. Bones found under 2·5 m. of peat in a probable peat-pond basin were dated 2,220±100 yr. (270 B.C.). Reduced diversity of aquatic plants and invertebrates on South Georgia is associated with greater distance from a source continent, colder temperatures and less mature wetlands.

DURING studies of austral waterfowl, I visited the Falkland Islands from October 1970 to January 1971 and South Georgia during November and December 1971. To relate habitat use to food utilization by ducks, it was necessary to classify wetlands and to sample invertebrates that constituted potential food resources. The wetland types found in the Falkland Islands were used in a summary of waterfowl habitat selection (Weller, 1972).

Among the most interesting ponds were those in the Falkland Islands and located in peat beds either on ridge tops or slopes. Subsequent work on South Georgia revealed ponds that may have resulted from similar forces. The formation of these peat ponds does not seem to have been treated in detail anywhere, and these observations are intended to encourage further study.

Macroscopic fresh-water invertebrates that may serve as duck food and emergent plants that may serve either as food or as a suitable substrate for invertebrates are also compared. It is obvious that the diversity of food resources determines the variety of potential niches for waterfowl and other fresh-water birds.

FALKLAND ISLANDS

A much greater variety of pond and lake types occurs on the Falkland Islands than on South Georgia. Seashore beaches impound streams partly or completely so that barrier ponds form. Such ponds may lack significant diversity and abundance of macro-fauna if they have bottom substrates of large stones lacking fine sediments suitable for invertebrates. Those on more gradual slopes, filled from large drainages that carry considerable sediment may be rich in both aquatic plants such as Native Water-milfoil (*Myriophylum elationoides*) and crustaceans such as Amphipoda.

Oxbow ponds occur along streams but they tend to be small because streams cut deeply into peat banks and meander slowly. Fig. 1 shows a series of stream-formed ponds on East Falkland. Stream pools are formed when channels are partly blocked by collapsing peat banks, or when the stream cuts through to varying depths, dependent upon the substrate.

Numerous ponds 6–20 m. above sea-level are in sand and probably resulted from stream and sea action at late Pleistocene sea-levels, which were up to 69 m. higher than at present (Adie, 1953; Cawkell and others, 1960). Sand-bottomed ponds are among the richest in flora and fauna because of their gently sloping bottom contours and shallowness near shore. Other large ponds, sometimes at the same altitude but in and surrounded by peat, had either peat bottoms or clay bottoms. Ponds on claypan were turbid, grey and often rich in invertebrates, although never with the diversity or density found in sand-bottomed ponds (Table I; Weller, 1972). All ponds in peat had steep sides, were uniformly 0·5–0·8 m. deep and were brown. Peat ponds were acid (pH 4·0–5·3 for 19 ponds), turbid and low in productivity, whereas one large sand-bottomed pond was less acid (pH 6·0), clear and more productive (Table I).

There are some large tarns at higher elevations that seem to have been formed in glacial

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Fig. 1. Meander stream and oxbow ponds in peat, south-east of Port San Carlos, East Falkland.

TABLE I. INVERTEBRATE DIVERSITY AND MEAN STANDING CROP OF BENTHIC FAUNA IN FITZROY PONDS, 5 NOVEMBER 1971 (FROM WELLER, 1972)

Pond	*Substrate*	*Sample size*	*Invertebrates*	
			Maximum number of taxa	*Mean* (ml./m.^{2})
Swan	Sand-clay	6	10	27·8
Fitzroy	Clay-peat	6	6	8·6
South Twin	Peat	6	4	7·7
North Twin	Peat	2	3	1·4

cirques (Clapperton, 1971; Greenway, 1972). Although I observed these from the air, I never had the opportunity to visit one on the ground.

Smaller and more abundant ponds occurred on the peat of certain ridges as occur north-west of Fitzroy and north-east of the Murrell River mouth. The ridge peat ponds are the most sterile faunistically but they were fascinating structurally (Fig. 2). Although many such ponds occur on slopes and in related series (Fig. 3), some straddle ridges at 150–200 m. (Fig. 2) and cover several hectares. These ponds had several things in common, and their formation may be a fairly simple process resulting from solifluction. Although I did not measure slopes, most smaller ponds probably are on slopes of 5–10°. Such slopes induce solifluction in Arctic permafrost areas (Hussey, 1962), but I doubt that there currently is significant freezing of soil even in winter in the Falkland Islands. The ponds rest in peat beds 0·7–1·0 m. deep, and eroded areas demonstrate that this peat layer rests on loose stones cemented by clay, or even on a claypan such as that shown in Fig. 4. The patterns of single ponds (Figs. 5 and 6) and series of ponds (Fig. 3) indicate that cracks form via solifluction. Extensive shifting

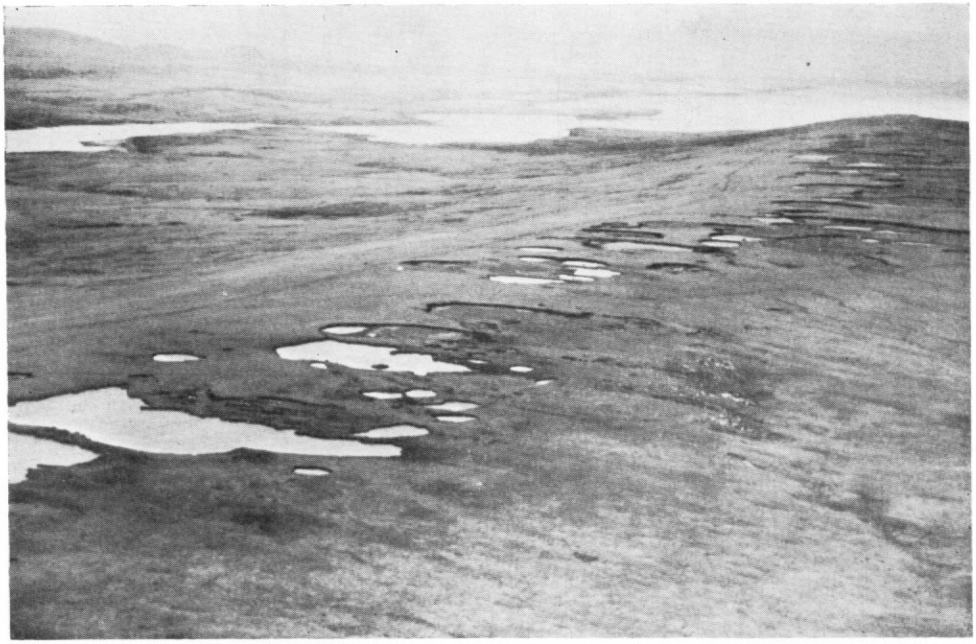

Fig. 2. Fitzroy Ridge ponds, south-west of Stanley, East Falkland. Orientated ponds are mainly north–south and straddle the ridge.

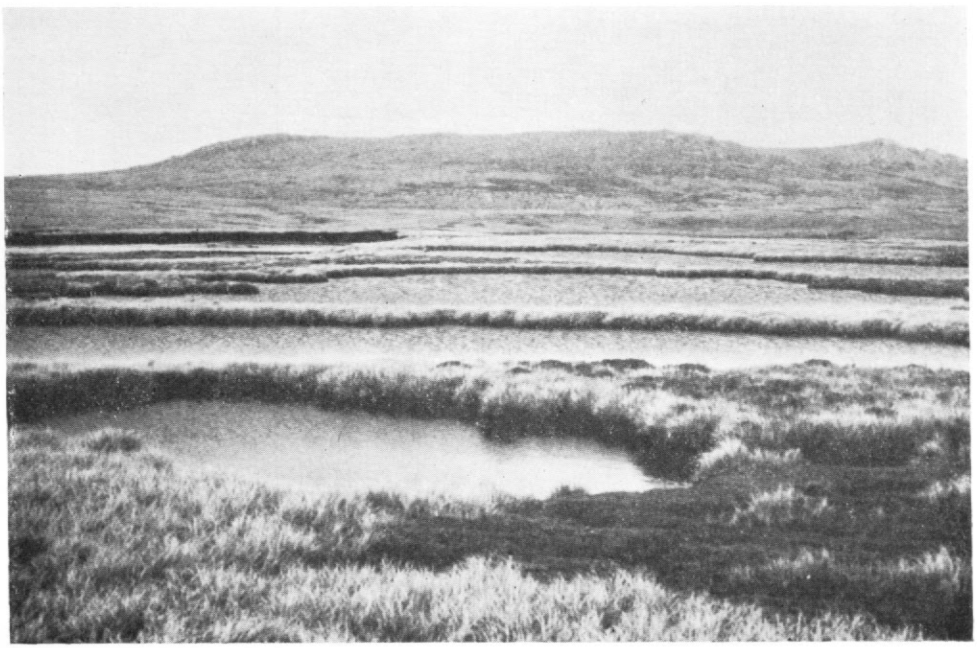

Fig. 3. Series of peat ponds on the slope east of the Murrell River, East Falkland.

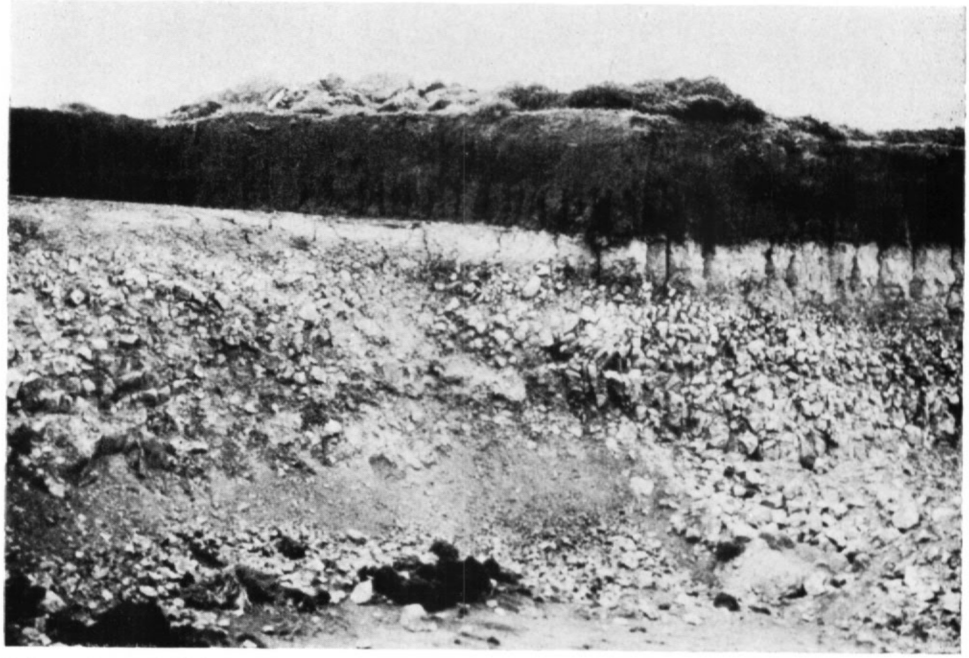

Fig. 4. Peat, clay and till layers exposed at Creek near Fitzroy, East Falkland. Note down-slope creep in rock below claypan.

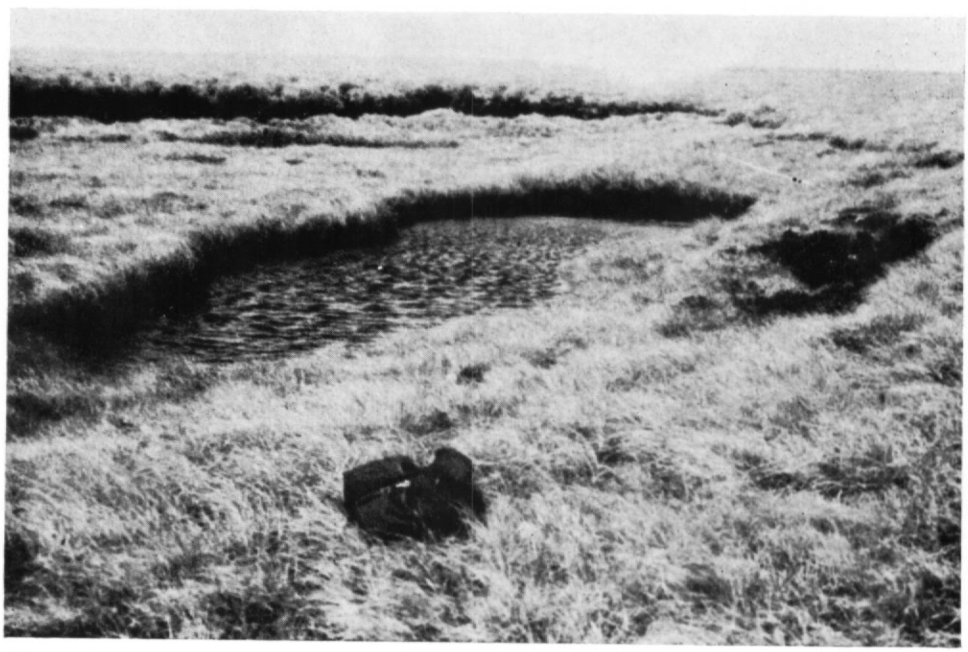

Fig. 5. Small pond formed in slump of shifted peat layer, Fitzroy Ridge. Back-pack in foreground.

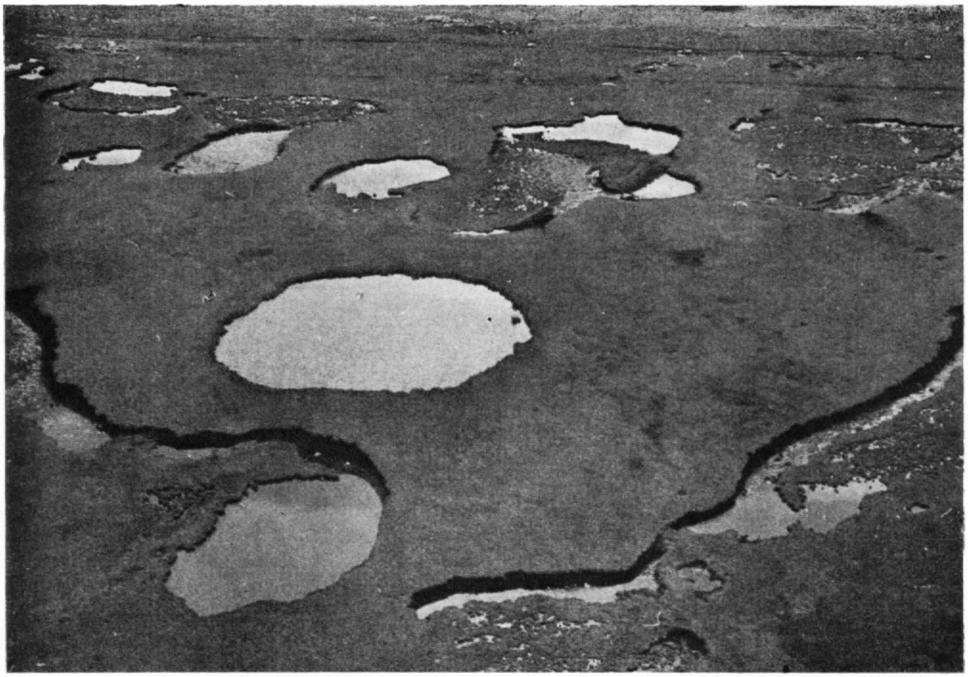

Fig. 6. Peat escarpments and ponds, Fitzroy Ridge.

of soil may produce escarpments of peat (Fig. 6) but small cracks form basins that eventually fill with water (Fig. 5). Growth of grasses and heath shrubs may temporarily seal the top of the peat and maintain the abrupt edges. Subsequently, wave action tends to cut the banks from below and maintain vertical sides.

Either by further solifluction or wind and wave action, ponds on the edges of slopes cut through the sod and drain, as shown in Fig. 7 and diagrammed in Fig. 8. Ponds on edges of slopes show greater drainage than do those on ridge areas with lesser slopes (Fig. 9).

Some ponds are circular (Fig. 6), and these may have been formed by cracks subsequently enlarged by wave action, or by drying and being eroded by the wind. The shallower ridge ponds dry completely in midsummer, and the role of drying and wetting in modifying soil structure must be considered. The formation of large ponds may be due to fusion of several ponds by wind erosion and further soil slippage, as suggested in Fig. 8. Ponds that straddle ridges probably start as dual series on either side of a ridge and two large ponds eventually fuse (Fig. 8). It is possible, however, that wind action is more important than solifluction once water basins are formed, as is true in the formation of the orientated lakes in Arctic permafrost zones (Carson and Hussey, 1962). Some of the larger ridge ponds at Fitzroy were orientated north and south with dominantly westerly wind direction (Fig. 2), but this probably was due to formation of ponds at right-angles to the ridge slopes.

Solifluction was first discovered in the Falkland Islands by Andersson (1906), who considered this the major force in the formation of the famous stone-runs. Although there is no evidence of extensive glaciation, cirque glaciers have occurred (Clapperton, 1971) and climatic conditions undoubtedly were more severe during the Pleistocene (Andersson, 1906; Adie, 1953). Andersson assumed that the major "mud-glaciers" occurred during these "subglacial" conditions, but he also recognized that freezing and thawing, or even wetting and drying, might induce solifluction.

Because escarpments of peat are neither eroded nor vegetated (Fig. 6), solifluction seems to be a current and active process. Alternate wetting or drying probably is more important

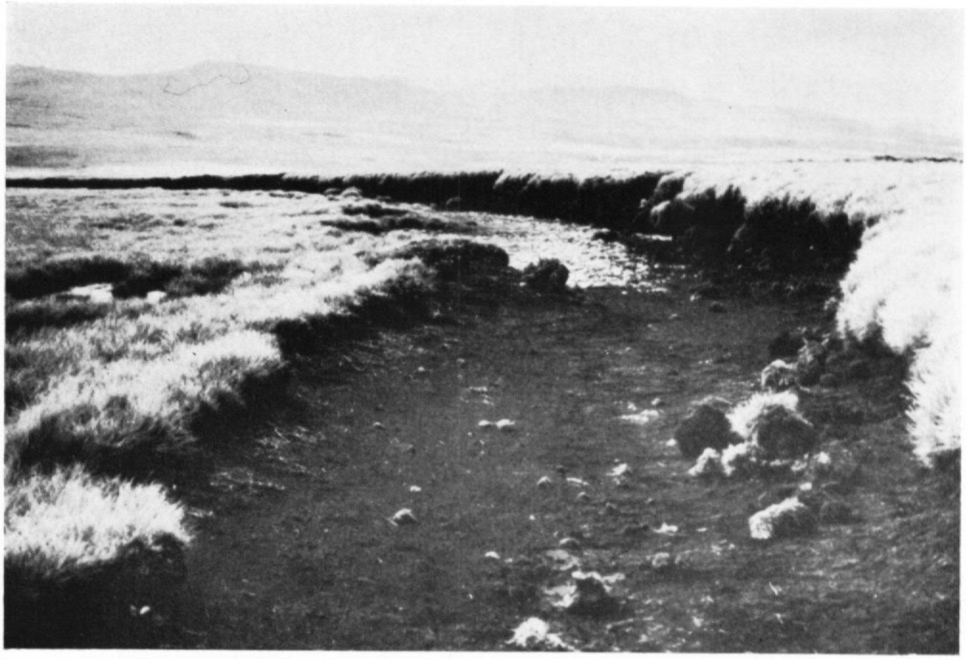

Fig. 7. Solifluction cleavage and exposed substrate in drained pond, Fitzroy Ridge.

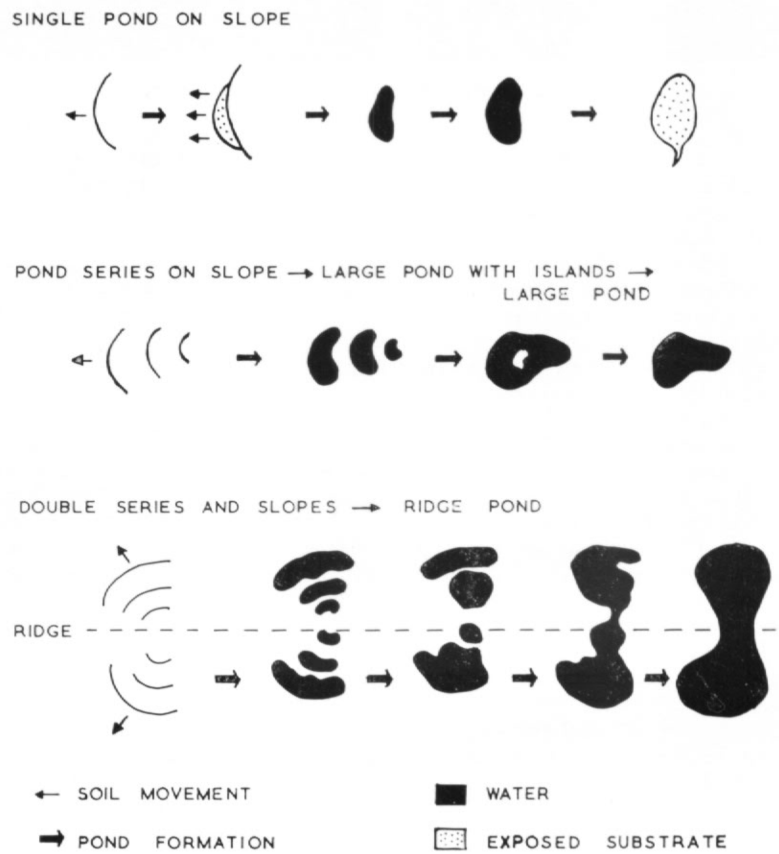

Fig. 8. Possible patterns of pond formation in ridge peat beds of the Falkland Islands.

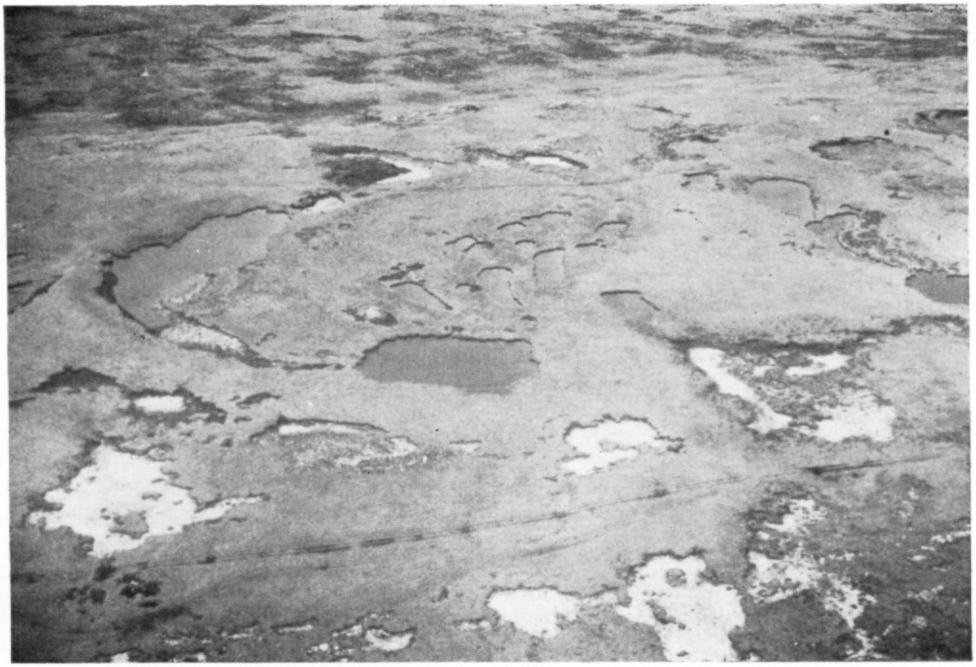

Fig. 9. Series of ponds presumably formed in a series of solifluction cracks. Ponds on more severe slope have drained and the substrate is exposed, Fitzroy Ridge.

than freezing and thawing but some freezing of peat presumably occurs at 200 m. altitude. Supersaturation was believed responsible for the only major peat slippage reported on the Falkland Islands, which destroyed houses in the town of Stanley (see Adie, 1972).

The age of these peat ponds is unknown, and even age of the peat does not seem to have been determined. Bones buried in a few centimetres of clay under nearly 2·5 m. of peat were assumed by Hattersley-Smith and Hamilton (1950) to have been from a pond subsequently filled by peat. I examined this site on West Point Island on 8 January 1971. It is located on a saddle between two hills but with two slopes to the sea, and it could have been a ridge pond. In all probability, the soil surrounding the pond was a nesting area for Magellanic penguins, which commonly swim in fresh water, but bones of other species also accumulated. Birds' bones collected for me from this site by R. Napier, M. Rumboll and S. Pettingill were dated at 2,220 $\pm$ 100 yr. by Teledyne Isotopes of Westwood, New Jersey, U.S.A. Although this date suggests that the layer of peat may have formed at a rate of about 9 yr./cm. since a pond existed, it may simply mean that solifluction from adjacent slopes covered the bones. More extensive ageing of peat beds in the area would be necessary to determine relative ages of peat in and around the presumed pond site. Nevertheless, the layer of clay and the bones strongly suggest that a pond existed there over 2,000 yr. ago.

South Georgia

In comparison with the Falkland Islands, South Georgia is currently glacierized, but seemingly is in a period of glacial recession. Pond formation there is more clearly a product of glacial action, but several other pond types occur.

Barrier ponds, being usually located on plains, are perhaps the most common wetland type. These are formed by barrier beach ridges that impound snow and ice melt water near sea-level, but the elevation of some of these ponds suggests a declining sea-level. Ponds of more than a hectare are rare, whereas barrier ponds of several hectares are common on the more level coastal terrain of the Falkland Islands.

Most of the ponds that I observed were formed in lateral moraines of receding glaciers. The ponds of Zenker Ridge and Dartmouth Point, west and east, respectively, of Moraine Fjord (Cumberland Bay) are prime examples. Ponds near Harker Glacier (Fig. 10) often are deep (2 m. or more), more sterile, clear and vegetated at the edges with sedges, grasses and other tundra plants. Ponds farther from the glacier (Fig. 11) are shallower, have a deep layer of debris, and are richer in aquatic invertebrates. These glacial ponds, as well as barrier ponds, often are surrounded by tussock grass (*Poa flabellata*), a plant that presumably needs richer soil than occurs on the gravel and rock beds nearer the glacier. It also creates deep peaty layers from its own decomposition; thus, time of substrate emergence from ice or sea may be a factor in the plant succession.

Ponds in other morainal debris may be much deeper, as at Maiviken, where some ponds probably exceed 4 m. These often have tussock grass surrounding them, but rarely is it of the density or height of growth found on deeper soils of areas with more mature ponds.

It is obvious that ponds also form by solifluction on South Georgia. Those that I encountered were on very steep, tussock-covered slopes of 20–35°, and their structure usually is simpler than that observed on the Falkland Islands. One pond of this type was in a bed of peat that had slipped and part of the pond basin extended over the edge of a cliff. Others were at various elevations along a steep hillside that originally formed the retaining wall of a glacier. These latter ponds were linear in shape and ranged from a few decimetres to nearly a metre deep. Wet meadows of similar shape and position obviously resulted from complete filling of such basins.

The age of these ponds is unknown but studies of glacial recession may yield estimates. A knowledge of the age of these ponds and the associated tussock fields would provide estimates of the time necessary for pioneering of fresh-water organisms.

Pond Macro-flora and Macro-fauna

Major taxa of invertebrates encountered, or are known to occur on the Falkland Islands or South Georgia, are compared in Table II. Although the invertebrates have been identified

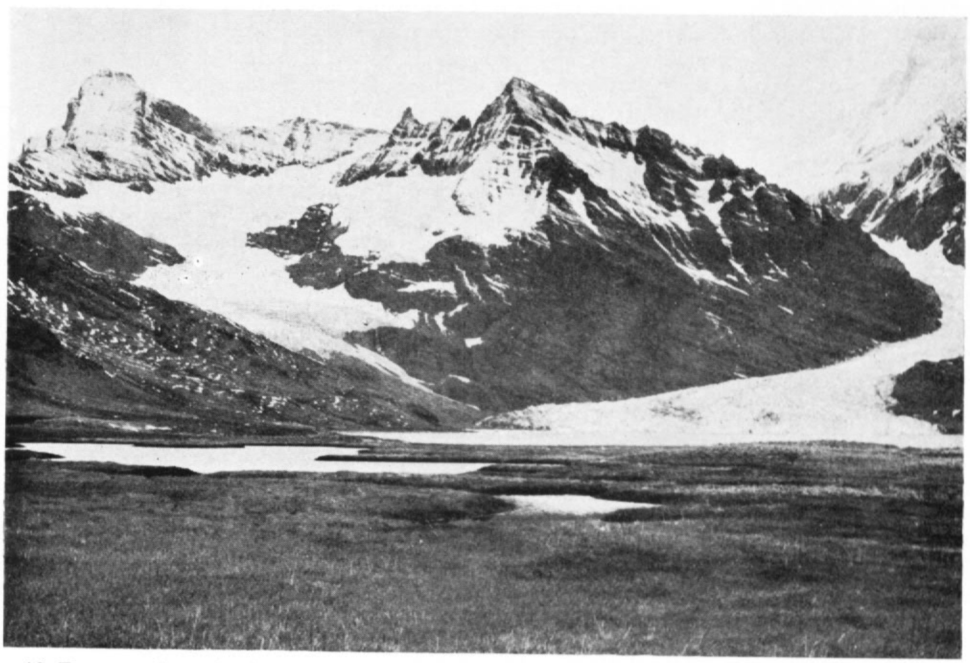

Fig. 10. Deep ponds resting in sedge-grass mats near Harker Glacier and Moraine Fjord, South Georgia.

Fig. 11. Shallow tussock-rimmed ponds about 3 km. from those shown in Fig. 10. Harker Glacier is in the background.

TABLE II. SOME GENERAL OBSERVATIONS ON FRESH-WATER POND ORGANISMS OF THE FALKLAND ISLANDS AND SOUTH GEORGIA

	Falkland Islands	*South Georgia*
INVERTEBRATES		
Gastropoda	x	
Pelecypoda	x	
Oligochaeta	x	x
Hirudinea	x	
Crustacea		
Anostraca	(x)	x
Cladocera	x	x
Copepoda	x	x
Amphipoda	x	x
Acari	(x)	x
Insecta		
Collembola	(x)	x
Hemiptera—Notonectidae	x	
Trichoptera	x	
Diptera (Chironomidae)	x (4 families)	x (1 family)
Coleoptera (Dytiscidae)	x	x

x Present.
(x) Present but not recorded in this study.

only to major taxa, there is a dramatic difference in the diversity of pond organisms on the two archipelagos. Obviously, the greater distance from a continental source fauna, cooler temperatures, increased acidity (pH 4·1–4·9 for 14 ponds) and presumably lower nutrient level have reduced taxonomic diversity of the South Georgia fresh-water ponds.

The fresh-water aquatic plants are shown in Table III and demonstrate the immaturity of

TABLE III. FRESH-WATER HIGHER PLANTS AS OBSERVED IN THIS STUDY (x) OR BY MOORE (1968) (*) FOR THE FALKLAND ISLANDS, AND BY GREENE (1964) FOR SOUTH GEORGIA (x)

	Falkland Islands	*South Georgia*
FRESH-WATER MACROPHYTES		
Eleocharis melanostachys (D'Urv.) (Spike-rush)	x	
Callitriche antarctica Engelem. ex Hegel	x	x
Montia fontana L. (Blinks)	*	
Lilaeopsis macloviana (Gandoger) A. W. Hill	x	
Calta sagittata Cav.	x	
Epilobium cumminghomii Hausskn	*	
Schoenopledus riparius (Presl) Palla	*	
Potamogeton linguatus Hagstr. (Native Pondweed)	x	
Myriophyllum elatinoides Gaudich (Native Water-milfoil)	x	

South Georgian ponds. In addition to the reduction in seed sources produced by the greater distance, few ponds on South Georgia have suitable substrates for emergents, such as *Eleocharis*, or submergents such as *Myriophyllum elatinoides*. This, in turn, reduces possible substrates for aquatic insects and crustaceans and thereby reduces niche diversity for fresh-water invertebrates.

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