most. Green algae do develop in back waters and the chrysomonad *Synura* has been found for example. The catchments carry a considerable animal population, both wild and domesticated, and as a result the waters have a considerable bacterial content. *Escherichia coli* may be found up to several thousand per 100 ml. and *Streptococcus faecalis* to a similar extent.

This may be compared with the Manawatu River which is somewhat sluggish and may have 10^6 or 10^7 green algae per litre and the river shows a definite diurnal photosynthetic oxygenation effect.

The estuary of the river is tidal and green filamentous algae are to be found as well as the intestinal bacteria of the coliform and enterococci groups together with the sulphur bacteria of the sulphate reducing types.

Forest Variation in the Hutt Catchment

A. P. Druce and I. A. E. Atkinson

The Hutt catchment has an area of 245 square miles, most of which is hilly and mountainous country above 1,000 ft. The average rainfall in the lower part of the valley (south of Te Marua) and on the Eastern and Western Hutt hills is 50-60in.; elsewhere it is 80-100in. or more, probably exceeding 150in. at 4,000ft. Originally more than 95% of the catchment was in forest. Today approximately 42% (103 sq. miles) still carries primary forest, although nearly all of it is to a greater or less extent modified. The present vegetation of the catchment is as follows (figures approximate):—

Primary forest	42%
Secondary forest and scrub	33%
Shrub and tussock land (part natural, part induced)	1%
Unimproved pasture	8%
Improved pasture	5%
Plantations (exotic trees)	2%
Built-up, gardens, playing fields, etc.	8%
Riverbed	1%

For mapping purposes the primary forest has been divided into fifteen community types (Table 1). The distribution of these is shown on the vegetation map. The large area of secondary forest and scrub includes much hill-country farmland in various stages of reversion, as well as a great deal of burnt-off hilly and mountainous land that has never been utilised. The most important species are manuka, gorse, tauhinu, and bracken. Further details are recorded on the back of the map.

A more detailed account of this work will appear later as a D.S.I.R. Bulletin.

The catchment has been divided into four vegetation areas (see map), according to whether certain physiognomic species are present or absent, as follows:—

1. *Western Hutt Hills Area:* all four beech species absent, kamahi local, kohekohe present in south-western part.
2. *Wakatikei - Akatarawa Area:* silver and red beech absent.
3. *Tararua-Rimutaka Area:* all four beech species present (forest unstable at altitudes above 2,800 feet).
4. *Mangaroa-Eastern Hutt Hills Area* (N.W. of the Climie - High Misty ridge): red beech absent.

In this paper, variation in vegetation is related to the primary factors, biota, soil parent material, climate, topography, and time. Such variation is either continuous or discontinuous. If, at one extreme, there is a sudden change in canopy composition, it may be said that a sharp boundary exists between two different community types (variation discontinuous). If the variation takes place over a limited distance, the boundary between the two types is diffuse (variation continuous over a limited distance). At the other extreme no boundary between community types can be discerned (variation continuous). In this paper, vegetation exhibiting discontinuity is described as a mosaic, that showing continuity described as a sequence.

CLIMATIC VARIATION

Figure 1 shows the variation in canopy composition with altitude in the Wakatikei-

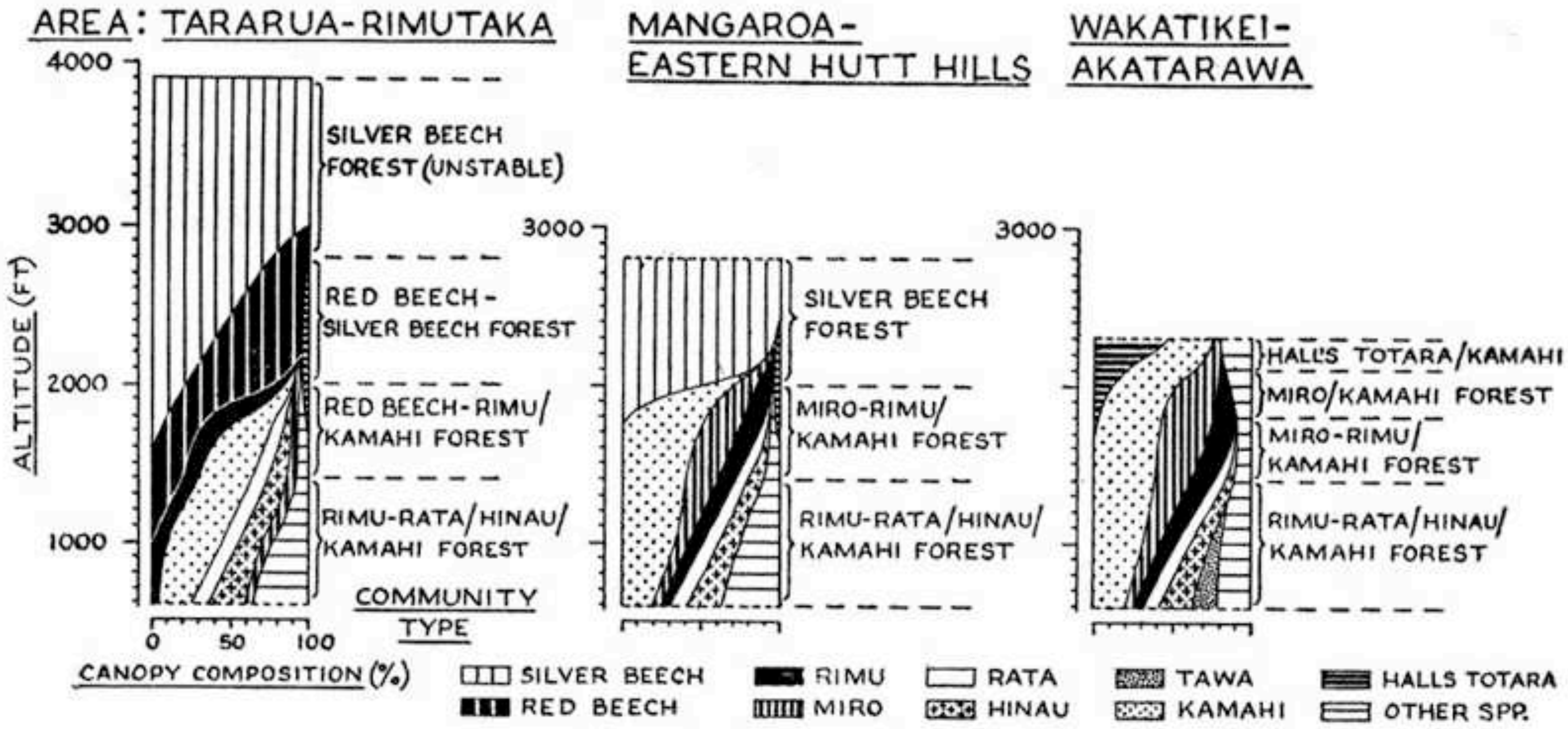

FIGURE 1.—*Altitudinal sequences in the Tararua-Rimutaka, Mangaroa - Eastern Hutt hills, and Wakatikei - Akatarawa areas of the Hutt catchment.*

Akatarawa, Mangaroa - E. Hutt hills, and Tararua - Rimutaka areas. These altitudinal sequences are based on both counts and qualitative estimates of the relative numbers of individuals of each species made on stable sites of moderate to steep slope. Variation is continuous up to the limit of forest vegetation and division of the sequences (cf. forest continua of Curtis and McIntosh 1951) into community types for mapping purposes is arbitrary.

In the Western Hutt hills area the only relatively undamaged remnant of forest (below Belmont Hill) is rimu-rata/tawa/kohekohe up to about 800 ft. and rimu-rata/hinau/tawa above that altitude. Rimu-rata/hinau/kamahi forest (milled) only occurs near the summit of Boulder Hill (1,445 ft.).

TOPOGRAPHIC VARIATION

On rolling slopes under a high rainfall, drainage becomes an important factor, the composition and height of the vegetation commonly changing as the slopes become less steep. Three examples of such topographic or drainage sequences at different altitudes in the Tararua-Rimutaka area are given below, where stands are compared on different sites. The community types of the ridge-tops are listed in Table 1. They are a feature of the Maymorn area in the Tararua mountains, but also occur in other parts of the catchment.

SITE	MAX. HGT. (ft.)	STAND
1. *Renata ridge, 3,000 ft. alt.*		
Steep ridge-side	50	silver beech.
Hilly ridge-side	25	silver beech.
Rolling ridge-top	10	silver beech — *Dracophyllum filifolium* (stunted trees).
2. *Maymorn ridge, 2,000 ft. alt.*		
Steep ridge-side	60	red beech-silver beech-rimu/kamahi.
Hilly ridge-side	60	silver beech-red beech-rimu/kamahi.
Rolling ridge-top	40	silver beech-rimu-Hall's totara-miro.
3. *Ridge above Pakuratahi forks, 1,400 ft. alt.*		
Steep ridge-side	70	hard beech.
Rolling ridge-top	60	hard beech-rimu.

Throughout the catchment, but more especially at higher altitudes in the Tararua-Rimutaka area, canopy height and composition change with aspect and exposure. These topographic or local climatic sequences are most commonly seen across ridges running at right angles to the prevailing north-westerly wind direction. The most striking examples occur in the Rimutaka mountains and along the Marchant ridge in the Tararua mountains. On a rounded ridge-top the sequence may be determined by both drainage and local climate together, but differences of drainage are not considered to be of primary importance in the example below.

ALT. RANGE (ft.)	COMMUNITY TYPE /Separates canopy layers. - Links species in same layer. *Indicates layer composed of scattered trees only.	TOPOGRAPHY	OCCURRENCE †Indicates that a large part of the forest has been cut-over.
2,800-3,900	Silver beech forest	hilly and steep lands	extensive, Tararua Mts.
2,000-2,800	Silver beech forest (with kamahi and toro in sub-canopy)		extensive in Rimutaka Mts. local in Tararua Mts.
2,000-2,800	Red beech-silver beech forest		extensive, Tararua and Rimutaka Mts.
2,100-2,400	Hall's totara-kamahi forest		local, Mts. Wainui and Maunganui.
1,800-2,100	Miro/kamahi forest		local, Wakatikei and Akatarawa hills.
1,400-2,000	Red beech-rimu/kamahi forest		extensive, Tararua and Rimutaka Mts.
1,400-2,000	Miro-rimu/kamahi forest		extensive in Wakatikei and Akatarawa hills. local in Rimutaka Mts.
500-1,400	*Rimu-rata/hinau/kamahi forest		†extensive in Wakatikei and Akatarawa hills, and Tararua Mts. remnants in Rimutaka Mts.
100-1.400	*Rimu-rata/hinau/tawa forest		†remnants in W. Hutt hills, Hutt Valley and tributaries.
100-800	*Rimu-rata/tawa/kohekohe forest		†few remnants in W. Hutt hills.
2,300-3,900	Silver beech-*Dracophyllum filifolium* forest	rolling ridge-tops	local, Tararua and Rimutaka Mts.
1,900-2,100	Silver beech-podocarp forest	rolling ridge-tops	local, Tararua Mts. (Maymorn area).
100-2,000	Hard beech forest	rolling, hilly and steep lands, and high terraces	many pockets and remnants (some large); absent from W. Hutt hills (S.W. of Boulder Hill).
100-1,200	Black beech forest	steep hillsides and low terraces	many small pockets and remnants; absent from W. Hutt hills (S.W. of Boulder Hill).
100-700	*Podocarp/tawa forest	riverflats	few remnants in Hutt Valley and tributaries.

TABLE 1.—*Forest community types of the Hutt catchment.*

MARCHANT RIDGE, 2,900 FT., S.W.-N.E. ALIGNMENT

Slope/Aspect	*Max. Hgt. (ft.)*	*Stand*
15°/N.W.	9	silver beech and a few red beech and *Dracophyllum filifolium* (canopy smooth).
0°	12	silver beech and a few Hall's totara (canopy smooth).
15°/S.E.	30	silver beech-red beech (canopy smooth).
30°/S.E.	60	red beech-silver beech (canopy uneven).

SUCCESSION (TEMPORAL VARIATION)

One method of constructing a hypothetical sere is to compare neighbouring stands of differing age. Seven examples of such mosaics are given below. In each of examples 2, 3, 4, and 5, the younger stand could well become, in time, similar in height and composition to the older one. In example 1 a difference in microclimate has led to a conspicuous difference in the form of the silver beech. In each of examples 6 and 7 the absence of juvenile rimu means that the younger stand will never approach the older one in either composition or structure.

AGE (yrs.)	MAX. HGT. (ft.)	COVER (% est.)	STAND
1. *Mt. Alpha, 3,800 ft. (timberline), hillside.*			
c. 52	9	100	silver beech (second generation saplings with erect stems).
c.250	9	100	silver beech (stunted first generation trees with very short boles and spreading crowns).
2. *E. Hutt headwaters, 3,600 ft., steep hillside.*			
c. 76	15	100	silver beech (saplings).
>200	40	10	silver beech (trees with small compact crowns).
3. *W. Hutt headwaters, 3,100 ft., steep hillside.*			
c. 66	22	100	silver beech (poles).
>200	60	25	silver beech (trees with small compact crowns).
4. *W. Hutt valley, 2,100 ft., steep hillside.*			
<100	40	100	silver beech-red beech (poles).
>200	60	100	red beech-silver beech (trees with spreading crowns).

5. *Near Mt. Kakariki, 1,700 ft., rolling ridge-top.*

<200	40	100	rimu - kamahi - miro - hinau (poles).
c.480	70	100	rimu - miro - rata - hinau / kamahi.

6. *Above Renata forks, 1,400 ft., steep hillside.*

<100	30	100	kamahi - hinau - red beech (poles).
>400	80	100	red beech-rata-rimu-miro/hinau/kamahi.

7. *Silverstream Bush, 400 ft., hillside.*

<100	30	100	tawa-hinau (poles).
>400	80	100	rimu/hinau/tawa.

Following the introduction of browsing animals, marked changes have occurred in the silver beech forest above 2,800 ft. Originally the forest had a dense subcanopy layer of shrubs (Zotov, 1949); today this layer is almost entirely missing. About five square miles is in an unstable state, the canopy cover averaging only 25% and the floor cover 50%. Seedlings of silver beech were abundant in June, 1958, but saplings were rare and those within reach severely browsed. The succession in the future, whether to forest degradation or to a closed cover of beech, depends primarily on the animal population.

LITHOLOGICAL VARIATION

Between either hard beech forest or black beech forest and any other community type there is almost invariably a sharp boundary. Any two of these contrasting community types adjoining one another form a mosaic. Between hard beech forest and black beech forest, however, there is usually a diffuse boundary and the vegetation forms a sequence.

Hard beech forest occurs widely in all regions except the Western Hutt hills, at altitudes up to approximately 2,000 ft., but is far from being universally present. In the Wakatikei-Akatarawa area it extends as far north as the middle reaches of the Wakatikei river, and in the Tararua mountains as far north as the Renata stream. It is widespread in the remaining areas with the exception of the upper Pakuratahi valley and the south and south-east slopes of Mangaroa valley. The forest adjoins the following community types, as well as others too small to map: rimu - rata / hinau / tawa, rimu - rata/hinau/kamahi, miro-rimu/kamahi, red beech-rimu/kamahi, red beech-silver beech, and podocarp/tawa. Ten examples, at altitudes from 1,800 ft. down to 500 ft., are given below in which site stands are compared in a mosaic. In each example the adjoining community types are on different soil parent materials.

STAND	SITE
1. *Above Renata forks, 1,800 ft.*	
Hard beech	very steep hillside (coarse rock debris).
Red beech - silver beech-rimu-miro/kamahi	rolling ridge-top.
2. *Above Renata forks, 1,600 ft.*	
Hard beech	very steep hillside (coarse rock debris).
Red beech - rata - rimu - miro/hinau/kamahi	steep hillside.
3. *Above Pakuratahi forks, 1,400 ft.*	
Hard beech-rimu	high river terrace.
Red beech - rata - rimu / hinau/kamahi	hillside below terrace.
4. *Mangaroa V., 1,100 ft.*	
Hard beech	very steep hillside.
Rimu-rata/hinau/kamahi	very steep hillside (fine rock debris).
5. *Above Wakatikei R., 900 ft.*	
Hard beech	ridge - top (truncated soil).*
Rimu-rata/hinau/kamahi	ridge-top.
6. *Above Pakuratahi forks, 700 ft.*	
Hard beech	steep hillside (rock and soil debris).
Rimu - rata - pukatea - matai/kamahi/mahoe	fan (fine stony colluvium).
7. *S.W. of The Plateau, 700 ft.*	
Hard beech	steep hillside.
Rimu - kahikatea - matai - pukatea - rata / tawa / mahoe	river flat.
8. *Silverstream Bush, 700 ft.*	
Hard beech-black beech	high river terrace.
Rimu/hinau/tawa	hillside above terrace.
9. *Silverstream Bush, 700 ft.*	
Hard beech - terrestrial rata	high river terrace (shallow silt over gravel).*
Rimu/hinau/tawa	high river terrace (deep silts).*
10. *Silverstream Bush, 500 ft.*	
Hard beech	steep hillside.
Mahoe-supplejack	fan (coarse stony colluvium).

*The authors are indebted to Mr. H. S. Gibbs for these soil identifications.

Black beech forest is not as widely spread as hard beech forest, and where it was most extensive on terraces in the Hutt valley, it has been largely destroyed. Pockets of black beech forest also occur on steep slopes in rimu-rata/hinau/tawa and rimu-rata/hinau/kamahi forests. Site stands in three mosaics are compared below. As in the last examples, the adjoining community types are on different soil parent materials.

STAND	SITE
1. *Above Pakuratahi forks, 1,000 ft.*	
Black beech	very steep hillside (rock debris).
Rata - rimu / kamahi / mahoe	steep hillside.

2. *Silverstream Bush, 300 ft.*	
Black beech	steep hillside (soil and rock debris).
Tawa-hinau	hillside.
3. *Bartons Bush, 150 ft.*	
Black beech	low river terrace.
Kahikatea/tawa	riverflat.

DISCUSSION

The present condition of the silver beech forest in the headwaters of the Eastern and Western Hutt rivers warrants immediate attention. Whether loss of a forest canopy is a result of senescence, wind or snow damage (cf. Zotov *et al*, 1938), slipping, or some other cause, does not alter the fact that browsing and destruction of juvenile trees by animals retards or prevents the formation of a new canopy.

The area affected, though only a small part of the total catchment (five square miles), is situated in a region where annual rainfall is at least 100 in. and perhaps as much as 150 in. Headward erosion and undercutting by streams is a continual process and slips may be expected no matter what the condition of the forest. In the absence of browsing animals canopy gaps formed by either slips or windfalls are soon filled by dense thickets of juvenile silver beech (see examples 1–3 under succession). At present however, this is not the case, and no other species with root systems extensive enough to stabilise steep slopes are able to establish. If present trends continue it is apparent that the greater part of the Eastern and Western Hutt catchment area above 2,800 ft. will become scree.

Loss of this high altitude forest may be expected to increase runoff, especially during periods of peak rainfall, as well as affecting stream grading. The magnitude of these effects on stream-flow in the Hutt river cannot be predicted accurately without an intensive investigation of the upper part of the catchment. No further investigation is required, however, to reach the conclusion that existing trends in forest deterioration can be related primarily to the presence of browsing animals. This conclusion is identical with that already reached by Zotov (1949).

Another significant change in forest composition is taking place in the rimu-rata/dicotylous forests below 1,400 ft. At these altitudes rimu usually occurs as a scattered emergent tree, often of large size. A few rimu seedlings and small saplings are found but tall saplings and young pole-size trees are generally absent. Rimu is apparently not maintaining itself in lowland parts of the catchment.

Between altitudes of 1,400 and 2,150 ft., however, both sapling and pole-size rimu may be found, particularly on poorly drained sites in red beech - rimu / kamahi, silver beech-podocarp and hard beech-rimu forests. No adequate explanation for this varied behaviour of rimu can yet be given but it seems possible that both recent climatic changes (Holloway 1954, Nicholls 1956, McKelvey 1958), and processes of soil development are involved.

Much of the forest variation described in this paper may be attributed to the absence of one or more of the four beech species: silver, red, hard, and black. In the Hutt catchment there are particularly good opportunities to study the interactions between these species and those of the podocarp/dicotylous forests. We have as yet little basic information on the biology of these species and it is this, together with more detailed knowledge of the climatic and geological history of the Hutt district, which will be required if an adequate understanding of forest variation in the catchment is to be reached.

APPENDIX

Key to Common Names Used in the Text:

black beech—*Nothofagus solandri.*
bracken—*Pteridium aquilinum* var. *esculentum.*
gorse—*Ulex europeaus.*
Hall's totara—*Podocarpus hallii.*
hard beech — *Nothofagus truncata (N.fusca* var. *colensoi).*
hinau—*Elaeocarpus dentatus.*
kahikatea—*Podocarpus dacrydioides.*
kamahi—*Weinmannia racemosa.*
kohekohe—*Dysoxylum spectabile.*
mahoe—*Melicytus ramiflorus.*
manuka—*Leptospermum scoparium.*
matai—*Podocarpus spicatus.*
miro—*Podocarpus ferrugineus.*
pukatea—*Laurelia novae-zelandiae.*
rata—*Metrosideros robusta.*
rimu—*Dacrydium cupressinum.*
red beech—*Nothofagus fusca.*
silver beech—*Nothofagus menziesii.*
supplejack—*Rhipogonum scandens.*
tauhinu—*Cassinia leptophylla.*
tawa—*Beilschmiedia tawa.*
toro—*Myrsine salicina (Suttonia).*

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