Variation in bird species abundance in a commercial pine plantation in New Zealand

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Abstract

The abundance of bird species in a commercial radiata pine plantation in New Zealand was studied to determine how different aged tree compartments affect birds. We found that exotic bird species were found in greater numbers than indigenous species in young and intermediate aged pine stands, but both were recorded in similar abundances in mature stands. Stand edges had higher overall densities of birds than the interiors of stands. Eight of the 31 bird species observed made up 89 % of birds recorded.

We found that the application of poison bait (1080) for pest control had no significant effect on bird density overall. The density of exotic bird species, however, was greatest where bait was applied from the ground over a small, localised area. Moreover, some individual indigenous species were recorded in their highest numbers in areas where bait had been aerially broadcast over a large area. Higher densities of birds were recorded at the start and end of the breeding season.

Our results indicate that in commercial pine forests, maximum avian diversity and density will result from a mosaic of pine stand ages with high local heterogeneity. Within this mosaic, stand edges and pine stands over 20 years old are particularly important. If conservation of indigenous bird species is the management aim, then older stands must be well represented throughout, and broadcast application of pest control over a wide area may be beneficial.

Key words: *bird density; edge effect; pine plantation; New Zealand; radiata pine; forest management; pest control*

1. Introduction

Because of the increasing demand for environmentally sustainable products, plantation forest owners face increasing pressure to develop management strategies sympathetic to indigenous biodiversity (Norton, 1998). If these strategies are to be successful, the factors influencing biodiversity must be thoroughly understood. Several studies have documented the suitability of plantation forests in New Zealand to indigenous and exotic bird species (Gibb, 1961; Jackson, 1971; Colbourne and Kleinpaste, 1983; Clout, 1984; Clout and Gaze, 1984) and reported that plantation forests are more suited to some species than others. For example, insectivorous bird species are generally abundant, whereas nectar feeders and obligate cavity nesters are less well represented (Clout and Gaze, 1984). Other factors determining bird species density and composition in plantation forests in New Zealand are less well understood.

Clear fell harvesting methods are used in both large-scale commercial and small-block farm forestry in New Zealand (Maclaren, 1996). While the harvesting method is the same, the size of the operation can have a marked effect on the landscape. Commercial forestry results in a mosaic of different aged stands of plantation trees across the landscape. In contrast, small farm forestry blocks are usually felled all at once and therefore does not have the different ages of stands across the plantation. Clear fell harvesting is perceived by some people to be environmentally harmful, mostly on aesthetic grounds (Potton, 1994). The size of clear fells in particular is controversial (Maclaren, 1996), although little effect of clear fell size has been recorded on bird species abundance in New Zealand (Spurr and Coleman, 2002) or overseas (Rudnicky and Hunter, 1993; Krementz and Christie, 2000). Edge habitats, relative to interior habitats, can have negative or positive effects on species abundance (Kroodsma, 1984). However, the effect of stand edges (the border between two age classes of pine stand) in commercial pine plantations is rarely taken into account. Knowing the relative abundances of bird species between the edge and the interior of a pine stand is, therefore, a key factor when considering the effect of clear fell forestry.

Introduced predators like mustelids, feral cats, black and Norway rats, have led to the decline or extinction of many indigenous bird species in New Zealand (Tennyson and Martinson, 2006). Forestry managers in New Zealand commonly use 1080 (sodium monofluoroacetate) poison bait to control plantation pests. This may also benefit bird populations by reducing potential predator numbers (Murphy *et al*., 1999). As a result, pest control is generally termed predator control by conservation managers. Identifying the method of applying 1080 poison bait that is most beneficial to indigenous bird species is important when considering their management.

As part of a study assessing the ecological requirements of the New Zealand falcon in plantation forests, we investigated bird species abundance and composition in Kaingaroa Forest. These bird count data are used to investigate the effects of forestry variables on the composition of bird species and their density in a commercial plantation forest. By understanding these relationships, foresters will

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be better placed to make management decisions to enhance bird populations within plantation forests.

2. Study area

Our study was conducted in the North Island of New Zealand in the pine plantation of Kaingaroa Forest. Kaingaroa Forest covers 180,000 hectares of mostly radiata pine (*Pinus radiata*), that is harvested in discrete blocks thereby creating a mosaic of different aged pine stands.

3. Methods

Bird species abundance was assessed using a belt transect census method (Bibby *et al*., 1992). A single observer walked along predetermined transects recording species in two 50m bands either side of each transect (0-50m and 50-100m). Inclement weather was avoided because of its negative effect on bird activity. Bird counts were carried out at least one hour after sunrise but before 10.00 am to reduce any effect of time-of-day and to allow direct comparisons of counts. To further reduce the effect of time, transects were repeated and the time at which they were started within this period was cycled. 700m transects were marked out in straight lines running North-South and where vegetation became thick, lines were pre-cut at least one week before surveys so that they could be walked quietly. Counts along stand edges were restricted to 500m because of the shape of the stands and the need to avoid the effects of neighbouring aged compartments.

Bird counts were conducted from October to February in 2004 and November to January in 2005. Study sites were chosen based on pine tree age and pest control treatment

Table 1. Categories of pest control and vegetation types assessed in the survey.

Study area	1080 pest control type	Pine stand class	Pine age class (years)	Pine height (m)	Dominant vegetation class	Under storey vegetation height (m)	Vegetation cover (%)
1	Localised ground control	Young	Less than 4	0.5	Exotic grasses and fleabane	0.2	10
		Intermediate	10 to 14	8	Indigenous and exotic scrub	1	70
		Mature	More than 20	25	Indigenous shrub	1.5	80
		Edge	<4 vs 20+	1/ 25	Grasses/ indigenous shrub	0.3/ 1.5	20/ 90
2	Aerial Broadcast control	Young	Less than 4	0.5	Exotic grasses and fleabane	0.3	30
		Intermediate	10 to 14	8	Indigenous and exotic scrub	1	90
		Mature	More than 20	25	Indigenous shrub	2	100
		Edge	<4 vs 20+	2/ 25	Grasses/ indigenous shrub	0.3/ 1.5	50/ 90
3	No control	Young	Less than 4	0.5	Exotic grasses and fleabane	0.3	20
		Intermediate	10 to 14	8	Indigenous and exotic scrub	1	100
		Mature	More than 20	25	Exotic grasses and indigenous scrub	0.3	70
		Edge	<4 vs 20+	2/ 25	Grasses/ indigenous shrub	0.3/ 1.5	50/ 90

type. In 2004, four compartment types were studied, young stands (containing pine trees less than four years old), intermediate stands (containing pine trees between 10 and 14 years old), mature stands (containing pine trees greater than 20 years old) and edge (the boundary between young and mature stands). In New Zealand, radiata pine matures between 25 and 35 years old and are generally felled at this time (Maclaren, 1996). The stand or compartment age classes were selected to represent a broad cross section of stand structure and ages from a typical New Zealand plantation forest (Table 1). Older stands of pine sometimes occur within these plantations but Pierce *et al*., (2002) found that bird species density changes very little after pine stands reach 25 years old. Thus, these older stands were not included in bird counts.

The four transect types were surveyed in each of three pest control treatment classes: localised ground control, aerial broadcast control and no-control (Table 1). In both ground and aerial control areas, 1080 bait was applied less than a year before the study. The no-control areas had not had bait applied for over three years. Localised control was restricted to just one or two compartments and bait was applied by hand, whereas with aerial broadcast, control baits were applied from a helicopter or aeroplane over a large area covering many compartments. Understorey vegetation characteristics were also noted along each transect, including mean vegetation height, vegetation cover and the dominant vegetation class (Table 1). Each transect was repeated twice a month, from October to February, in each age class and each pest control treatment type.

In 2005, transects were selected in six types of edge habitat between pine stands of different ages (0-5 years, 0-10 years, 0-20 years, 5- 10 years, 5-20 years and 10-20 years). These transects were replicated in four different aspects: north, south, east and west (where aspect is the direction perpendicular to a transect line, facing away from the older stand), were repeated twice in each aspect, twice a month from October to February. These transects were spread over the whole forest irrespective of pest control type.

The bird count data were converted into density per hectare by fitting a linear function. Data were divided into three classes for analysis: indigenous birds, exotic birds, and a combined data set where all bird species were pooled. Relationships between forestry variables and bird abundances in each class were investigated with a general linear model. Repeated measures were similar and the residuals were determined to be normal, thus further analysis was deemed unnecessary.

4. Results

4.1. Overall bird species abundance

Overall, chaffinches (*Fringilla coelebs*) were the most abundant species, making up 32 % of the bird species in Kaingaroa Forest (Fig. 1). Eight species out of the 31 species recorded during this study, made up 89 % of the bird species, including four indigenous species, silvereye (*Zosterops lateralis*), whitehead (*Mohua albicilla*), tomtit (*Petroica macrocephala*) and grey warbler (*Gerygone igata*). Rifleman (*Acanthisitta chloris*) were recorded only in mature stands and although they have been recorded in pine forests before (Jackson, 1971), are notably lacking from some other plantation forests (Clout and Gaze, 1984). The New Zealand pipit (*Anthus novaeseelandiae*) was also recorded here but is often absent from other plantation forests (Clout and Gaze, 1984).

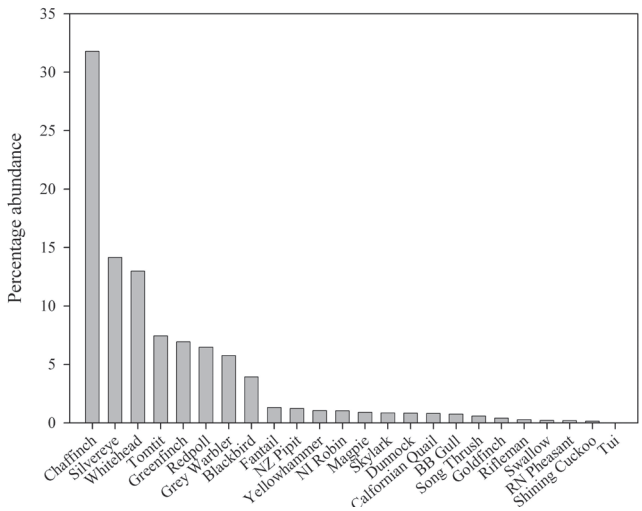

Figure 1. Abundance of bird species in Kaingaroa Forest (percent)

4.2. Variation in bird assemblage and abundance between the interior and edges of stands

In 2004, overall densities of birds were higher along stand edges than in the interior of pine stands ($F_{3,120}=25.92$, $P<0.0001$). The mean density of bird species per hectare in each pine stand class ranged from 140.9 at the forest edge (the boundary between young and mature pine stands); 83.8 in mature stands (trees more than 20 years old); 75.4 in intermediate aged stands (pine trees between 10 and 14 years old) and; 46.6 in young stands (containing pine trees less than four years old).

4.3. Variation of the bird species and abundance in different aged pine stands

The overall density of birds increased with pine stand age ($F_{2,90}=19.06$, $P<0.0001$), although there was no significant difference between intermediate and mature

stands. Indigenous species density increased with stand age ($F_{2,90}$=48.21, P<0.0001), while exotic bird density did not vary between stand age classes ($F_{2,90}$=0.54, P=0.59). The composition of bird species broadly changed from specialist open habitat species to forest dwelling indigenous species as pine stand age increased (Table 2 on Page 8). Chaffinches were the most abundant species recorded in all age classes (Table 2).

When accounting for stand age, all stand edges show higher densities than interiors (Tables 2 and 3 on Page 9) , and even when not accounting for age this was usually the case. Overall densities of bird species did not vary significantly between stand edge classes ($F_{5,47}$=1.07, P=0.40). Exotic and indigenous species, however, did vary significantly between stand edge classes ($F_{5,47}$=4.42, P=0.006; $F_{5,47}$=4.02, P=0.009). Exotic species were found at their highest densities along transects bordering unplanted stands, whereas indigenous species generally favoured stand edges that included mature stands (Table 3). Chaffinches were the most abundant species in all but three stand edge categories, where silvereyes and whiteheads were recorded as more abundant (Table 3).

No difference was recorded in the assemblages of species between the centres or edges of pine stands, although North Island robins (*Petroica australis*) were slightly less well represented along stand edges containing mature pines, than in the centres of mature stands, suggesting they might prefer the interior of pine stands over edges (Tables 2 & 3).

4.4. The influence of the aspect of a stand edge on bird species abundance

The aspect of an edge had no influence on the abundance of birds ($F_{3,47}$=1.01, P=0.41), which suggests that prevailing weather and shelter also had little effect. However, bird counts were only carried out in fine weather to avoid bias in detection, therefore densities of bird species could potentially vary with aspect in different weather conditions.

4.5. Variation in bird abundance between pest control (1080 poison bait) application types

There was no recorded difference in bird density between pest control (1080 poison bait) application types ($F_{2,120}$=2.02, P=0.14). However, the density of exotic birds was highest where pest control was localised ($F_{2,120}$=5.07, P=0.008), which was mostly attributable to the greater densities of chaffinches and greenfinches (*Carduelis chloris*) in this treatment area (Table 4 on Page 10). Indigenous birds, were found at similar densities in all three treatment types ($F_{2,120}$=0.02, P=0.98). Some indigenous species, however, were recorded at higher densities in pine stands where 1080 had been aerially broadcast over a large area, these included whitehead, grey warbler and tomtit (Table 4).

4.6. Variation in bird abundance over the breeding season

Bird density was greatest at the start and at the end of the breeding season with 93.2 and 75.5 birds per hectare in October and February respectively ($F_{4,120}$=23.71, P<0.0001). During the intervening months the densities of bird species averaged 59.4 per hectare Both exotic and indigenous species followed this trend ($F_{4,120}$=12.34, P=0.0007; $F_{4,120}$=18.56, P<0.0001). This trend results from seasonal variation of chaffinches, whiteheads and silvereyes. Most other species remained relatively stable (Table 5 on Page 11).

5. Discussion

The edges of pine stands had greater densities of birds than the interiors of pine stands. Species inhabiting edge environments have the opportunity to increase the diversity of food available to them by using several habitat types, while remaining close to cover from predators (McCollin, 1998). The greater densities of birds located along stand edges in our study suggests that smaller stands will promote higher densities of birds than larger stands.

Overall, we found bird density increased with pine stand age. In contrast, Clout and Gaze (1984) recorded no increase in overall bird density with pine stand age. However, this may be due to the fact that they ignored stands less than six years old (which we class as young pine stands) and they investigated a wider range of stand ages (six to 48 years) and they recorded bird species twice a day using five-minute bird counts as opposed to the early morning transect method we employed. Finally, they counted birds at two times of the day, one in the early morning and one in the early afternoon.

Our results highlight the importance of the retention of mature stands in the landscape for shelter, protection, breeding sites and feeding grounds. Thus, to maintain overall species density as well as high numbers of indigenous bird species, forestry managers should aim to have mature stands over 20 years old located throughout a plantation.

High local heterogeneity of pine stand ages is the key to maintaining high abundances and of both indigenous and exotic bird species in pine forests. High densities of indigenous bird species have inherent value in New Zealand, but high densities of some exotic species are also proving to be important in the landscape as they encourage high numbers of the endemic New Zealand falcon (*Falco novaeseelandiae*) (Stewart and Hyde, 2004), a species that is thought to be in decline elsewhere in New Zealand (Gaze and Hutzler, 2004).

Small-scale pest control can be less efficient than broadcast control over a large area due to the shorter reinvasion distances involved (Warburton and Thomson, 2002). Exotic birds, particularly finches, were denser in areas where ground bait was applied on a small scale but the reason for this is not clear and may be unrelated to pest control. It has been shown that bird counts do not measure bird abundances on a scale fine enough to show the differences caused by pest control unless the effects are substantial (Atkinson *et al*., 1995). However, we recorded some indigenous bird species at their highest densities where 1080 poison bait was applied aerially over a large area. Thus, large-scale aerial application of bait may be more beneficial to the conservation of indigenous species than more localised pest control.

In conclusion, maximum avian density and diversity will result from a mosaic of pine stand ages with high local heterogeneity. Within this mosaic, stand edges and pine stands over 20 years old are particularly important. If indigenous bird species conservation is one of the management objectives, then older stands must be well represented throughout the plantation and the broadcast application of pest control over a wide area will be beneficial.

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Table 2. Mean densities of bird species per hectare in each stand class in Kaingaroa Forest, 2004. Young stands (containing pine trees less than four years old), intermediate stands (containing pine trees between 10 and 14 years old), mature stands (containing pine trees greater than 20 years old) and edge (the boundary between young and mature stands). Bold: Indigenous bird species.

	Pine stand class			
Bird species	**Young**	**Intermediate**	**Mature**	**Edge**
New Zealand pipit	**4.00**	**0**	**0**	**0.24**
Tomtit	**1.86**	**8.04**	**7.50**	**8.33**
Grey warbler	**1.21**	**7.58**	**3.82**	**7.30**
Silvereye	**0.69**	**7.62**	**6.16**	**34.40**
New Zealand falcon	**0.48**	**0**	**0**	**0.12**
Whitehead	**0.12**	**7.00**	**21.02**	**16.69**
Australasian harrier	**0.12**	**0**	**0**	**0.36**
Fantail	**0.12**	**1.07**	**1.67**	**1.67**
North Island robin	**0**	**0.48**	**2.20**	**0.91**
Shining cuckoo	**0**	**0**	**0.36**	**0.12**
Black-backed gull	**0**	**0**	**0**	**2.57**
Tui	**0**	**0**	**0**	**0.12**
Rifleman	**0**	**0**	**0.36**	**0.60**
Yellowhammer	1.99	0.12	0	1.50
Goldfinch	1.19	0	0.12	0.12
Australian magpie	0.60	0.36	0	2.14
Dunnock	0.24	1.21	0.60	0.83
Welcome swallow	0.24	0	0	0.48
Blackbird	0.18	4.83	4.19	4.37
Songthrush	0.12	0.76	0.66	0.48
Californian quail	0.12	0.71	0	1.90
Ring-necked pheasant	0	0.12	0.07	0.48
Indigenous	**8.60**	**31.79**	**43.09**	**73.43**
Exotic	38.00	43.60	40.70	67.46
All birds	46.60	75.39	83.79	140.89

Table 3. Mean densities of bird species per hectare in each stand edge class in Kaingaroa Forest, 2005 (e.g. 5/20= a five year old pine stand bordering a 20 year old pine stand). Bold: Indigenous bird species

	Stand edge class					
Bird species	**5/20**	**5/10**	**10/20**	**0/5**	**0/20**	**0/10**
Silvereye	**30.50**	**15.34**	**18.83**	**13.00**	**6.09**	**22.53**
Whitehead	**19.75**	**6.13**	**31.50**	**0.63**	**17.31**	**1.92**
Tomtit	**7.93**	**5.29**	**7.79**	**3.00**	**6.79**	**6.79**
Grey warbler	**6.79**	**9.36**	**6.75**	**3.00**	**6.91**	**2.79**
Fantail	**2.63**	**0.50**	**1.00**	**1.00**	**2.50**	**3.00**
North Island robin	**1.00**	**0**	**0.55**	**0**	**0**	**0**
New Zealand pipit	**0**	**1.00**	**0**	**2.00**	**0**	**0**
Australasian harrier	**0**	**0.50**	**0**	**0.50**	**0**	**0**
Tui	**0**	**0.50**	**1.00**	**0**	**0**	**0.50**
Chaffinch	23.32	22.26	19.49	24.42	26.62	17.28
Greenfinch	6.00	6.38	2.00	2.84	9.30	6.13
Redpoll	3.78	5.18	3.57	10.85	9.42	13.77
Blackbird	1.50	2.69	5.29	2.43	5.09	9.38
Ring-necked pheasant	1.50	0	0	0.63	0.50	0
Dunnock	1.50	2.00	5.50	4.00	3.00	6.00
Songthrush	1.00	0.79	0	0	0.50	1.00
Australian magpie	1.00	0	0.50	2.50	0.79	3.00
Californian quail	1.00	5.00	1.00	5.18	5.59	5.50
Yellowhammer	0.50	0.63	0	3.29	0	1.34
Starling	0	0	0	0	0	3.50
Skylark	0	0	0	1.13	0	0
House sparrow	0	0	0	0	0.50	1.50
Goldfinch	0	0.50	0	0	0	4.00
Indian myna	0	0	0	1.00	0	1.00
Indigenous	68.60	38.62	67.42	23.13	39.60	37.53
Exotic	41.10	45.43	37.35	58.27	61.31	73.40
All birds	109.70	84.05	104.77	81.40	100.91	110.93

Table 4. Mean densities of bird species per hectare in each of three 1080 pest control application types in Kaingaroa Forest. Bold: Indigenous bird species.

	1080 application type		
Bird species	**No control**	**Localised ground control**	**Aerial broadcast control**
Silvereye	**14.79**	**19.83**	**14.25**
Whitehead	**14.77**	**13.65**	**16.40**
Tomtit	**7.99**	**8.67**	**9.07**
Grey warbler	**6.14**	**4.96**	**8.80**
New Zealand pipit	**1.79**	**1.26**	**1.19**
North Island robin	**1.49**	**0.66**	**1.42**
Fantail	**1.19**	**2.14**	**1.19**
Rifleman	**0.83**	**0**	**0.12**
New Zealand falcon	**0.60**	**0**	**0**
Shining cuckoo	**0.36**	**0.12**	**0**
Welcome swallow	**0.24**	**0.48**	**0**
Australasian harrier	**0.12**	**0.24**	**0.12**
Black-backed gull	**0**	**2.45**	**0.12**
Tui	**0**	**0.12**	**0**
Chaffinch	32.25	43.64	33.96
Greenfinch	6.28	10.46	7.21
Redpoll	3.81	7.15	11.38
Blackbird	3.37	4.75	5.46
Australian magpie	1.17	0.78	1.14
Skylark	1.10	1.46	0.36
Dunnock	0.62	1.67	0.60
Californian quail	0.60	1.79	0.36
Yellowhammer	0.24	1.62	1.75
Songthrush	0.18	0.43	1.41
Goldfinch	0.12	0.60	0.71
Ring-necked pheasant	0	0.55	0.12
House sparrow	0	0.12	0
Indigenous	50.31	53.58	52.68
Exotic	49.74	75.02	54.46
All birds	100.05	128.60	107.14

Table 5. Mean densities of bird species per hectare each month in Kaingaroa Forest. Bold: Indigenous bird species

	Month				
Bird species	**October**	**November**	**December**	**January**	**February**
Silvereye	**15.48**	**2.62**	**1.90**	**13.79**	**15.09**
Whitehead	**14.44**	**10.60**	**8.79**	**4.96**	**6.03**
Grey warbler	**7.50**	**4.35**	**3.58**	**2.66**	**1.82**
Tomtit	**5.73**	**4.09**	**5.85**	**5.45**	**4.59**
New Zealand pipit	**1.43**	**0.71**	**0.83**	**0.95**	**0.31**
North Island robin	**1.14**	**0.33**	**0.34**	**0.87**	**0.90**
Fantail	**0.83**	**1.07**	**0.95**	**0.48**	**1.19**
Australasian harrier	**0.24**	**0**	**0.12**	**0**	**0.12**
Welcome swallow	**0.24**	**0**	**0.48**	**0**	**0**
Shining cuckoo	**0.12**	**0.24**	**0**	**0.12**	**0**
New Zealand falcon	**0.12**	**0.48**	**0**	**0**	**0**
Black-backed gull	**0**	**0.12**	**0.00**	**0.12**	**2.33**
Tui	**0**	**0.12**	**0.00**	**0**	**0**
Rifleman	**0**	**0**	**0.36**	**0.60**	**0**
Chaffinch	29.76	18.22	17.35	14.48	30.03
Greenfinch	4.65	5.05	6.51	3.95	3.78
Blackbird	3.24	2.52	3.19	1.30	3.33
Redpoll	2.80	6.19	4.48	5.91	2.96
Skylark	1.36	0.89	0.41	0.15	0.12
Yellowhammer	0.99	0.48	0.89	0.54	0.71
Australian magpie	0.93	0.07	1.07	0.60	0.42
Songthrush	0.93	0.48	0.38	0.12	0.12
Dunnock	0.60	0.73	0.24	0.95	0.36
Ring-necked pheasant	0.31	0.12	0.12	0.12	0
Californian quail	0.24	0.24	0.60	0.71	0.95
Goldfinch	0.12	0	0.24	0.71	0.36
House sparrow	0	0.12	0	0	0
Indigenous	**47.27**	**24.73**	**23.20**	**30.00**	**32.38**
Exotic	45.93	35.11	35.48	29.54	43.14
All Birds	93.20	59.84	58.68	59.54	75.52