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silviculture

Salvage Logging by Indigenous People in a Chilean Conifer Forest

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Salvage logging has been described as a controversial environmental practice in developed countries, but in developing countries this conflict has not been evaluated. We describe salvage logging of *Fitzroya cupressoides*, an endemic conifer of the South American temperate forests. In Chile, the Huilliche—an ethnical group—extract deadwood of *Fitzroya* to produce sawn timber and shingles. The objectives of this study were (i) to estimate the volume of deadwood that is removed by salvage logging performed by Huilliches and (ii) to evaluate the effects of this local activity on the regeneration of *Fitzroya*, especially regarding the amount of waste wood left behind. In 54 (10 $\times$ 10 m) plots we measured length, height and dbh of logs, snags, and stumps. We quantified the regeneration of *Fitzroya* by counting all individuals with heights below 2 m. Each plot was characterized by its altitude, slope, aspect, microtopography, canopy cover, and quantity of waste wood covering the forest soil. We found a total of 279.51 m^3 of deadwood of which 53.9% was rotten and 3.6% was used to make sawn timber and shingles. Contrary to expected, the number of seedlings (1–50 cm) was positively related to waste wood. Juvenile's density (1–200 cm) was mainly explained by altitude, microtopography, and the interaction of these variables with slope. We concluded that salvage logging by Huilliches is an activity that removes a minimum of the ecosystem biomass. It apparently has no negative effects on the regeneration of *Fitzroya,* which is explained mainly by biotic and some abiotic factors, especially altitude.

Keywords: burned forests, cubication, deadwood, ethnoecology, *Fitzroya cupressoides*, southern temperate forests

Salvage logging is the practice of felling or removing dead trees from forest areas that have been damaged by forest-fires, floods, storms, plague breakouts, insect infestation, or other natural disturbances (Lindenmayer et al. 2008). Recent reviews of the ecological effects of salvage logging have lead to the conclusion that the extraction of deadwood can severely delay ecosystem recovery. The result of this activity is hampering regeneration and deteriorating ecological key processes, such as nutrient retention and hydrologic cycles (Foster and Orwing 2006, Lindenmayer and Noss 2006, Lindenmayer and Ough 2006, Reeves et al. 2006, Schmiegelow et al. 2006, Gonzalez and Veblen 2007, Lindenmayer et al. 2008). For example, dead logs can act as reservoirs for bacterial, fungal, and invertebrate communities, which promote nutrient cycling and provide resources for establishing seedlings (Lindenmayer et al. 2004, 2008). The effects of salvage logging on ecosystem processes, however, differ depending on the practice itself. It has been found that practices that remove tree remnants, snags, plus coarse woody debris could be among the most damaging (Lindenmayer and Noss 2006). Therefore, careful analysis of salvage logging methods across various forest ecosystems is required to assess its effects on forest recovery.

Cases of salvage logging have been mainly studied in developed countries, where private companies or national forestry services are responsible for extracting deadwood from disturbed forests. In developing countries, however, the practice of salvage logging has remained largely ignored, despite the fact that it is a common practice among local people. That is the case for people from Vietnam, who live near vast areas of forests that are burned every year (Goldammer 1992), and in *Araucaria araucana* forests in Chile (Gonzalez and Veblen 2007). Nevertheless, salvage logging has been promoted by environmental groups (Thomas and Twyman 2005, Butler 2008). In their opinion indigenous and poor rural communities should be allowed to harvest the waste wood left by forestry companies or natural catastrophes).

Here, we provide a quantitative assessment for the practice of salvage logging by indigenous people in forests dominated by the long-living and economically valuable conifer *Fitzroya cupressoides* (Mol.) Johnston (Cupressaceae). *Fitzroya* belongs to a monotypic

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genus, endemic to southern Chile and Argentina. In Chile, timber of *Fitzroya* underwent heavy extraction since the 16th century, first by the Spaniards and then by Chilean and international forestry companies. This timber was exported in large amounts to foreign countries. The use of fire for land clearing, agriculture, and tree plantations, mainly during the 18th to mid-20th centuries, left around 50,000 ha of burned *Fitzroya* stands (INFOR 2008). Facing this scenario, the Chilean government banned the extraction of live *Fitzroya* trees as of 1976 and allowed only the gathering of deadwood from degraded stands. But, salvage logging of *Fitzroya* is, to this day, a rather controversial issue in Chile.

Fitzroya is a light-demanding pioneer that recovers in burned sites in the thin, metamorphic soil of the coastal range. In the Andean mountains, this recovery takes place on landslides and following volcanic activity, disturbances that are generally absent in the coastal range (Lara 1991). In coastal forests, *Fitzroya* regenerates mainly by gap-phase dynamics created by wind throw (Armesto et al. 1994). Humans have introduced a new disturbance, which is fire. The frequency and intensity of anthropogenic fires have increased in the last few decades. In spite of being logged and/or burned, many sites in the coastal forests show a high *Fitzroya* regeneration (Cortés 1990, Smith-Ramirez 2006). This phenomenon is probably due to its high capacity in using the nitrogen present in those impoverished soils (Pérez et al. 1998).

Currently, most of the *Fitzroya* deadwood is gathered by Huilliche families. Local communities of this ethnic group gather deadwood from both burned and logged coastal *Fitzroya* forests (Smith-Ramirez 2007). More than 120 families of seven Huilliche communities make their living by selling rustically processed wood products from salvage logging activities (Molina et al. 2006). Nowadays, Huilliches use low-quality deadwood remaining from trees logged 30–80 years ago. This deadwood is used by Huilliches to make shingles and second selection sawn timber. Production of both shingles and sawn timber is done on the site where the deadwood is found; following the products are transported by foot or with the help of horses or oxen. As a result of this activity, both coarse and fine woody debris are left in the forest. This waste wood can have potentially detrimental effects on the regeneration of *Fitzroya.* It is proposed that nutrient reductions by extraction of wood changes soil carbon-to-nitrogen ratios and produces soil acidification. Both these processes might have detrimental effects on the seedling and sapling establishment (Veblen et al. 1976, Donoso et al. 1993). Despite the potential threats of deadwood extraction, there are no estimates as to how much of it is left behind and how much is removed from the sites by indigenous gatherers. One study reported abundant but variable *Fitzroya* regeneration in a series of burned stands on the Chilean coastal range (Smith-Ramírez 2007); however, this variability was not associated with the quantity of waste wood present in these sites.

Accordingly, the objectives of this study were (i) to estimate the volume of deadwood that is removed from the ecosystem by salvage logging performed by Huilliches and (ii) to evaluate the effects of this local activity on the subsequent regeneration of *Fitzroya*, especially regarding the amount of waste wood left behind.

Methods

Study Area

This study took place in the Manquemapu indigenous territory, Osorno Province, in southern Chile (40° 51′ S; 73° 48′ W). Thirty Huilliche families work almost exclusively on gathering deadwood from degraded stands of *Fitzroya*. We made a participatory meeting with *Fitzroya* workers to obtain qualitative information. Participatory method is one in which everyone who has a stake in the intervention has a voice, either personally or by representation (van Maanen and Barley 1984). This method has been amply recommended by social science to obtain qualitative information (van Maanen and Barley 1984). To carry out this study, the workers chose a stand called La Ranfla, which has an estimated average volume of harvestable deadwood comparable to other stands in the study area.

La Ranfla is a 50 ha forest stand located at an altitude of 674 m above sea level, which was almost totally destroyed by a fire about 35–45 years ago. *Fitzroya* is highly inflammable conifer due to its resin contents. La Ranfla began being harvested by indigenous people at a low intensity 50 years ago. In the early 1990s extraction intensified when axes were replaced by chainsaws.

In this area, the forest is dominated by *Fitzroya* plus angiosperm species such as *Drimys winteri* (Winteraceae), *Nothofagus nitida* (Nothofagaceae), and *Tepualia stipularis* (Myrtaceae). Fern species are also present in this forest, mainly *Blechnum* and *Gleichenia* genera, Ericaceae shrubs, mosses, and sedges (Cyperaceae), indicating humid soil conditions.

To measure deadwood we made small 10 × 10 m plots. The suitable number of plots was decided using a presample, following Zohrer (1980), which was originally developed for live trees. Using this formula, live trees were replaced by logs, snags, and stumps, yielding a minimum estimate of 49 plots. Finally, our survey was carried out along 9 transects, with 6 plots per transect, which amounted to 54 sampling plots. The transect length was 50 m, with 30 m between transects. Transects were north-south oriented, including 70–100% burned adult stands, across landscapes with varying slopes. In each plot, we identified fallen logs, snags, and stumps of *Fitzroya* and measured the following variables: widest and narrowest diameter for logs and snags; length of logs (for all logs > 1 m in length); length of trunk up to the first canopy branches; and rotted wood areas. In the case of the stumps, we measured their diameter at the logging section. As for the logs, we measured dbh from the point we considered the tree to emerge from the soil up to 1.3 m. We measured the length of the logs strictly at the border of the plot (Vann et al. 1998).

Volume Determination of Deadwood

We used the Smalian equation to determine the volume of dead logs (Prodan et al.1997) as follows

$$V = [(g_s + g_i) \times L] \times \frac{1}{2}$$

V is the gross cubic volume (m^3); g_s is the area (m^2) of the large end of the log; g_i is the area (m^2) of the small of the log; and L is the length of the log (m).

The function used to determine the volume of snags for coastal *Fitzroya* was defined by Donoso et al. (1987) and is as follows

$$VB = = -6.08051e^{-4} + 8.10604e^{-5} \times D^2 + 6.1803e^{-4} \times D \times HCC + 1.99e^{-5} \times D^2 \times HCC$$

VB is the gross volume (m^3); D is the dbh (cm); and HCC is the starting height of branches (m).

The geometric function of a cylinder was used to determine stump volume, that is

$$V = \pi \times \left(\frac{D}{2}\right)^2 \times H$$

D is the diameter (m) and H is the height (m).

Due to the fact that most of the deadwood was partially rotten, we defined rot categories for each type of deadwood. Each rot category was assigned a percentage value of deadwood remaining useful, as estimated by the Huilliche workers by a participatory methods (van Maanen and Barley1984). They distinguished five categories of rot that affect the making of shingles and sawn timber (Maturana 2008). Each rot category was assigned a percentage of still useable wood. These categories were: central rot (remaining usable wood approximately 50%), peripheral-partial (usable wood 40%), intermediate (usable wood 30%), peripheral (usable wood 25%), and total (only for nonusable wood). These rot categories were used to establish wood rules to be applied in this study (see Appendix).

Tree Shingle and Log Rules

We measured each dead tree individually to select the portions of wood that could be used for making shingles and sawn timber. Sawn timber or "base" is a rectangular log of a specific length and width, which volume was 77, 308.96 cm^3 (see Appendix and Smalian equation). Although it is possible for timber values to be higher than this, undamaged logs are rarely found (without cracks). The volume of each shingles was 445.05 cm^3.

Regeneration

We recorded the number of regenerated *Fitzroya* in 1 × 1 m plots within every 10 × 10 m plots. We divided the regeneration into two different classes: (1) 1–50 cm (seedlings) and (2) 1–200 cm (juveniles). Due to the extremely slow radial growth of *Fitzroya* (Lara and Villalba 1993, Armesto et al. 1994) and the fact that La Ranfla stand was originally harvested 35–45 years ago, we assumed that waste wood (chips of different sizes) could have affected seedlings but not necessarily juveniles. We chose these intervals expecting only seedlings to be affected by waste wood. Furthermore, in 31 of these plots we made a distinction between vegetative and sexual reproduction seedlings. Vegetative seedlings are thick and have an irregular stem as opposed to seedlings from seeds that are thin and symmetrical.

Independent Variables

The independent variables were: green-tree cover, deadwood, altitude, soil microtopography, slope, and aspect of each plot. The percentage of green-tree cover was estimated visually and classified it using ranks of 0, 25, 50, 75, and 100%. Deadwood was visually estimated as a percentage of ground cover in four randomly assigned subsamples within the plots. Soil microtopography was summarized by four categories: flat, hollow, mound (convex), and microsite slope. Slope of each plot was reduced to three factors: 0–33°, 34–66°, and 35–100°.

The aspect of each plot was reduced to two factors, which were related to the prevailing winds in coastal southern forest of Chile: windward aspect directly receiving rain and sun (west, southwest, northwest, and north) and protected aspect, receiving less rainfall and sun (south, east, northeast, and southeast).

Table 1. Volumes (m^3) of rotten, nonrotten, and total deadwood of *Fitzroya cupressoides* trees in 54 plots in La Ranfla stand in the indigenous Manquemapu territory.

Logs	Total deadwood	Nonrotten wood	Rotten wood
Average by plot	3.82	1.93	1.89
Coef. variation (%)	104.29	113.60	123.71
Standard error	0.60	0.33	0.35
Median	2.24	1.21	1.184
Total logs (m^3)	184.71	89.41	95.29
Snags			
Average by plot	1.49	0.47	1.02
Coef. variation (%)	84.91	99.60	109.90
Standard error	0.21	0.07	0.18
Median	1.11	0.27	0.58
Total snags (m^3)	53.72	17.01	36.63
Stumps			
Average by plot	1,17	0.63	0.53
Coef. variation (%)	107.60	120.00	116.70
Standard error	0.21	0.12	0.10
Median	0.85	0.40	0.42
Total stumps (m^3)	41.10	22.37	18.73
Total	279.53	128.79	150.65

Statistics

General linear models were used to estimate species regeneration as a function of biotic and abiotic variables. Separate models were fit to the number of seedlings and juveniles. We used Poisson error distribution and a log link function to test the effects of different abiotic and biotic factors on regeneration. We chose Poisson error to deal with nonnormal error distribution and to avoid log-transforming counts, as suggested by O'Hara and Kotze (2010). Predictor variables were microtopography, slope, aspect, altitude, and green-tree cover and the dependent variable was seedlings or juveniles counts. In both analyses, a full model was fitted to the data and then reduced to a minimal adequate model by sequentially removing terms from the complete model, starting with the highest-order interaction terms (Crawley 2002). We used analysis of variance (ANOVA) to test for significant differences between models. Analyses were done using *glm* in R, version 2.7.1.

Results

Diameters and Volumes of Rotted Deadwood

Overall, we found 279.51 m^3 of deadwood in the 54 plots that represented a total volume of 518.7 m^3ha^{-1}. From this total, 443.6 m^3ha^{-1} were classified as nonrotten wood, following the classification used by the Huilliches (Table 1). Snags that were usable for the Huilliches are higher than 40 cm dbh. Usable fallen logs and stumps were mainly represented by individuals with dbh > 30 cm (Figure 1A; Appendix). The highest percentage of usable sawn timber was found primarily in logs (66%), then in snags (19%), and finally in stumps (14%) (Figure 1B).

In the survey, we found a total log volume of 184.7 m^3, represented by 208 individuals, with 0–15 logs per plot (Table 1). Nonrotten logs represented 24% (n = 50) of all individuals and 15% (n = 31) were totally rotten (Figure 1B). We found that 24.5% (n = 51) of the logs were too small to be used for making shingles or sawn timber (Figure 2; Appendix).

We found a total snag volume of 53.7 m^3, represented by 220 individuals, with 0–14 snags per plot (Table 1). Nonrotten snags represented 16% (n = 35) of all individuals and 33% (n = 73) were totally rotten (Figure 1B).

We found a total stump volume of 41.1 m^3, represented by 73

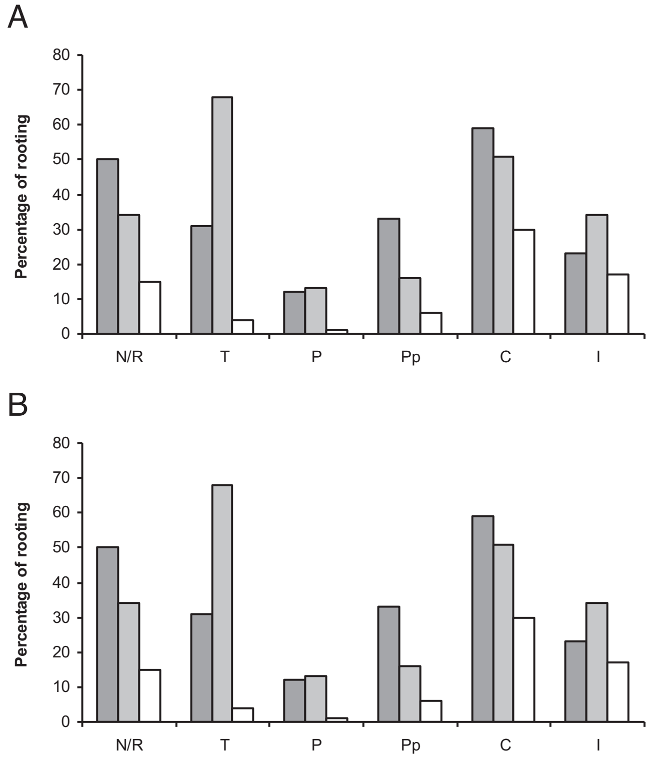

Figure 1. (A) Dbh of deadwood *Fitzroya cupressoides* individuals in La Ranfla stand of the indigenous Manquemapu territory. (B) Number of deadwood *Fitzroya cupressoides* individuals by rotten category. N/R = nonrotten, T = totally rotten, P = partially rotten, Pp = peripheral-partially rotten, C = centrally rotten, and I = intermedially rotten. Logs are represented by gray, snags by light gray, and stumps by white bars.

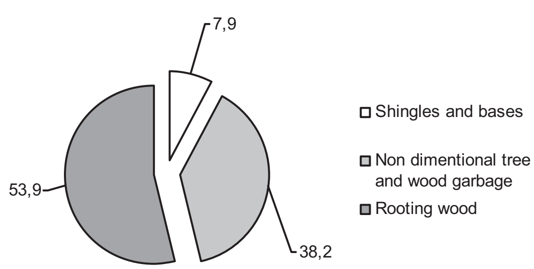

Figure 2. Percentage volume (m³) of rotten wood, nonusable wood, waste wood, and shingles and bases (sawn timber) of deadwood from *Fitzroya cupressoides* forests in La Ranfla stand in the indigenous Manquemapu territory.

individuals, with 0–5 stumps per plot (Table 1). Nonrotten stumps represented 21% ($n = 15$) of all individuals and 5% ($n = 36$) were totally rotten (Figures 1B and 2).

Cubication

After cubication of each class of deadwood (logs, snags, and stumps) we obtained 511 shingles and 128 sawn timbers (Table 3). The total volume of shingles was 423.6 cm^3 and the total volume of sawn timber was 546.9 cm^3 (Appendix). The total volume of usable wood amounted to 970.5 cm^3, which represented 3.6% of deadwood left (Figure 2). Remaining deadwood was represented by waste wood and small trees with nonadequate dimensions, as well as edgings, slabs, sweeps, and sawdust.

Regeneration

In the 54 plots we found 7,799 individuals $\leq$ 2.0 cm-height, estimating 14,444 individuals ha^{-1}. Seedling regeneration represented 74% ($n = 5{,}772$) of this density; the juveniles represented 26% ($n = 2{,}027$). In the 31 plots where we studied the origin of seedling regeneration, we found that 24% ($n = 1{,}385$) were from seeds and 66% ($n = 3{,}809$) from sprouts; 10% of them were not possible to be assessed.

Waste wood, and the interaction of waste wood with altitude, were positively and linearly related to seedling abundance (1–50 cm tall; Table 2A). The average percentage of ground covered by waste wood was 48.8% $\pm$ 29.4 (1 SD). The effect of slope and aspect were highly significant too, particularly the interaction of these terms.

Green-tree cover was positively related to seedling abundance (Table 2A), in spite of only finding 22 live adult trees in 19 of the 54 plots. The reason for this might be the strong vegetative and seedling reproduction under the trees.

Juvenile individuals (1–200 cm tall) were mainly affected by microtopography and altitude, which explained 18% of model deviance (Table 2B). More regeneration was found in hollows and higher altitude. Interaction slope $\times$ microtopography had positive and significant effect on juveniles. Higher regeneration was found in medium slope. Aspect had a significant effect as well, showing a higher regeneration where the rainfall and the sun radiation were more direct (northern aspect). These results suggest that environmental conditions, especially microtopography and altitude seem to play a key role in the density of *Fitzroya* juveniles (Table 2B).

Discussion

We found that high spatial variation in the volume of logs, snags, and stumps in burned *Fitzroya* forests, pointing to how variable and context-dependent the left deadwood is. High variation coefficients were associated to high variability in the dimensions of deadwood. The only report previously available estimated 241.6 m^3ha^{-1} of deadwood (approximately half of which was found in this study), for an area located south of Manquemapu (Wolodarsky-Franke et al. 2005). Wolodarsky-Franke et al. (2005) did not include the stumps, which represented 14% (rotten plus nonrotten) of deadwood volume found by us. Accordingly, to obtain a more reliable assessment of the general situation of deadwood in burned *Fitzroya* forests, it is necessary to evaluate density of different deadwood types in several stands. We found a high percentage (96.1%) of total deadwood volume will remain in the La Ranfla forest after salvage logging. The proportion of nonusable woody material by Huilliches is similar to the amount of waste wood lost resulting from timber elaboration of *Pinus radiata*, (González 2006), where 30% of the usable wood is wasted. Even though a small quantity of acceptable quality wood is removed from burned forests by Huilliches, the waste wood resulting from the elaboration of shingles and sawn timber eventually covers a high proportion of the forest ground (48.8%). It has been argued that the large fraction of ground covered by waste wood is liable to reduce the regeneration density of *Fitzroya* (Veblen et al. 1976). This applies to plots that showed 90–100% of waste wood cover, in which we found a small quantity of seedlings per plot (average = 7.2, rank 0–29). But, in this study we reported a positive relationship between these parameters in plots where the percentage of wood cover was low and medium (0–89%). We do not know what causes these patterns. The wood cover might aid in retaining the seeds and seedlings that could be washed away by heavy rainfall

Table 2. Results of *glm* for biotic and abiotic variables and interaction terms of seedlings (1–50 cm), and juveniles (1–200 cm) of *Fitzroya cupressoides* in a coastal forest in southern Chile. (A) In seedlings, the best model explained 80.7% total deviation. (B) In juveniles, the best model explained 64% of total deviance.

(A)	d.f.	Deviation	Residual d.f.	Residual dev.	Explained dev.	
Null	53	882.61				
Waste wood	1	21.968	52	860.64	2.489	***
Slope	1	29.768	51	830.88	3.373	***
Aspect	1	0.099	50	830.78	0.011	NS
Microtopography	**1**	**196.956**	49	**633.82**	**22.315**	***
Altitude	**1**	**36.066**	48	**597.75**	**4.086**	***
Green-tree cover	**1**	**57.634**	47	**540.12**	**6.530**	***
Waste wood × slope	1	6.456	46	533.66	0.731	NS
Waste wood × aspect	1	21.214	44	512.08	2.404	***
Slope × aspect	1	13.063	43	499.02	1.480	***
Waste wood × microtopography	1	21.525	42	477.49	2.439	**
Slope × microtopography	1	15.752	38	458.32	1.785	*
Aspect × microtopography	1	5.554	37	452.77	0.629	NS
Altitude × waste wood	**1**	**40.412**	36	**412.36**	**4.579**	***
Waste wood × slope × microtopography	1	8.946	32	398.89	1.014	***
Waste wood × aspect × microtopography × altitude	1	35.415	31	363.48	4.013	**

(B)	d.f.	Deviation	Residual d.f.	Residual dev.	Explained dev.	
Null	53	1,133.96				
Slope	1	38.25	52	1,095.71	3.37	***
Aspect	1	55.28	51	1,040.43	4.88	***
Microtopography	**3**	**120.04**	50	**920.38**	10.59	***
Altitude	**1**	**82.91**	49	**837.47**	7.32	***
Green-tree cover	3	30.99	48	806.48	2.74	***
Slope × aspect	1	27.22	47	779.26	2.40	***
Slope × microtopography	**3**	**90.59**	46	**688.67**	8.00	***
Aspect × microtopography	3	46.42	45	642.25	4.10	***
Slope × aspect x microtopography	2	50.19	44	586.89	4.43	***
Slope × aspect × altitude	1	4.43	43	582.46	0.39	*
Slope × microtopography × altitude	**3**	**95.51**	42	**486.95**	8.43	***
Aspect × microtopography × altitude	2	59.42	41	427.53	5.24	***
Slope × aspect × microtopography × altitude	0	0.1	40	427.53	0.01	NS

Chi-square test (χ^2) significance *$P < 0.01$, **$P < 0.001$, ***$P < 0.0001$. In bold, the four terms that reduced the most deviance.

Table 3. Number of useful (nonrotten and with adequate dimensions) logs, snags, and stumps and numbers of shingles and timbers cubicated for each deadwood type and rotten categories of *Fitzroya cupressoides* tree.

Rot categories	Stump numbers in 54 plots	Shingle numbers from stumps	Stump numbers from snags	Shingle numbers from snags	Log numbers in 54 plots	Sawn timber numbers by logs	Snag numbers in 54 plots	Sawn timber numbers from snags
Central	2	63	0	0	19	27	0	0
Intermediate	7	44	6	33	11	28	6	10
Peripheric-partial	1	16	1	4	12	20	1	1
Peripheric	0	0	0	0	2	7	0	0
Nonrotten	3	251	6	100	18	26	7	9
Total	13	374	13	137	62	108	14	20

(approximately 4,000 mm annually). Additionally, the main regeneration found was sprouts, which are less light dependent and grow faster than seedlings to become established (Bond and Midgley 2001). Thus, the partial shadow of coarse woody debris might not affect the sprout regeneration. Accordingly, we propose that coarse woody debris could facilitate seed and sprout regeneration of *Fitzroya* in coastal forests, given the environmental protection it might be able to provide. From our analyses, it became clear that abiotic conditions play an important role in determining the density of *Fitzroya* regeneration. Furthermore, the regeneration density was highly dependent on the presence of live *Fitzroya* remnants. There are probably more sprouts and seedlings around these trees than in plots without live *Fitzroya* trees. *Fitzroya* regeneration in the entire burned Manquemapu forests proved to be extremely high, between 13,000 to 26,800 individuals ha^{-1} ($\leq$ 2 m height; four stands studied); (Smith-Ramírez 2007). These rank values are similar to those found in La Ranfla, as reported here. Cortés (1990) also reported high regeneration of *Fitzroya* in logged and burned coastal forests in northern Manquemapu. He estimated up to 43,000 juveniles ha^{-1} (from 0.1 to 2.0 m in height). In *Fitzroya* coastal forest, a difference of Andean forest, fire has been prescribed to promote its secondary succession (Cortéz 1990). But, there is no information regarding *Fitzroya* regeneration after several fire cycles. The regeneration dependence of conifer forests after fire has been amply reported in other studies (Heinselman 1989, Fyllas et al. 2008). But, fire on *Fitzroya* accompanying species, which are not adapted to them (Lara et al. 1999), seems to have a considerably greater impact to the ecosystem than the gathering of small quantities of *Fitzroya* burned wood. Accordingly, improved fire prevention policies are needed to facilitate the ecosystem recovering in the vast areas of burned *Fitzroya* forests. The same policies should be applied to protect primary *Fitzroya* forests.

As suggested by Lindenmayer and Noss (2006), careful analyses of each case of salvage logging are necessary to properly assess the positive or negative effects on each forest ecosystem. We think this is the first scientific report to discuss a specific case of salvage logging by indigenous people. In this report, we found indigenous people removed small amounts of *Fitzroy*a wood without affecting its regeneration. Probably, similar salvage logging practices in third world regions may show similar results. In developed countries, on the contrary, the practice of salvage logging takes place at an industrial scale negatively influencing ecosystem processes. This negative effect has been amply reported in the scientific literature.

We conclude that indigenous families remove only a minor fraction of deadwood left in burned *Fitzroya* stands, but their work produces high quantities of waste wood. We show that waste wood does not seem detrimental to the regeneration of *Fitzroya* in the burned coastal stands. The regeneration of *Fitzroya* varies strongly depending on biotic and abiotic variables, such as green-tree cover, altitude, microtopography, and slope.

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Appendix: Tree Shingle and Sawn Timber Rules

We applied the cubication rules on logs to be used for timber. The rules were also applied on stumps for shingles and on snags for both timber and shingles. The minimum dimensions of deadwood to be used for timber were: width 17.8 cm, length 17.8 cm, and height 2.44 m. Dimensions for shingles were: width 10.8 cm, length 61 cm, and thickness 7 mm. To develop the rules for shingles, it was necessary to determine an inner perimeter that represented the gyration radius of shingles in each stump. The center of stumps and the edges of each shingle were lost as nonusable wood. Estimated number of shingles = radious/0.7 (0.7 is a shingle's thickness). 5.7 cm to be cut as edgings were obtained using the Prodan et al. (1997) wood rule.

Steps to apply cubication rules in logs and snags

1. First, snags and logs with total rot were discarded.

2. We only considered cubication for snags > 3.84 m height (2.44 m [timber] + 1.4 m [average stump height for shingles]) and logs > 2.44 m long.

3. We only considered snags and logs with diameter > 29.2 cm (17.8 cm + [5.7 cm*2]).

4. After that, we classified remnant snags and logs by rot type.

5. We discarded all snags and logs with central rotting and diameter < 116.8 cm (29.2 cm*4) and considered 50% wood loss (see Methods).

6. We discarded all snags and logs with intermediate and peripheral-partial rotting with diameter < 29.2 cm (17.8 cm + 5.7 cm * 2).

7. We considered a 75% wood loss in snags and logs with peripheral rotting with radious > 15.65 cm (17.8/2 + 6.75). In this case, nonrotten timber was in the center of the trunk.

Steps to apply cubication rules in stumps

1. First, we discarded all stumps with total rot.

2. We only applied the cubication rules to stumps > 66 cm, adding a margin of 5 cm to the rotten area, as it is nonusable.

3. We discarded stumps < 21.6 cm (10.8*2) in diameter.

4. After that, we classified each stump by rot type.

5. We calculated the gyration radius for the extraction of shingles by defining a new radius (*R*) as $r = 2\pi$ (10.8 – radio).

6. We discarded all stumps with rotten center and radio < 43.2 cm (10.8 cm * 4). A new internal radius was calculated.

7. We discarded 25% (see Methods) of shingles generated from stumps with partially rotten periphery.

8. We discarded 30% (see Methods) of shingles generated from stumps with rotten intermediate area.

9. We discarded 40% (see Methods) of shingles generated from stumps with totally rotten periphery.