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EFFECTS OF HARVESTING OF THE NAMIBIAN KELP (*LAMINARIA PALLIDA*) ON THE RE-GROWTH RATE AND RECRUITMENT

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ABSTRACT

The split-fan kelp (*Laminaria pallida*) also known as the Namibian Kelp is one of the most important kelp resources along the Namibian coast. Harvested kelp is used mainly as feed supplements for abalone culture as well as sources of alginate for industrial and medical purposes. In this field study, the effect of harvesting kelp by cutting the fronds at various lengths (0, 15, 30, and 40 cm from the stipe for treatment T_1, T_2, T_3 and T_4, respectively) was investigated. A total of eighty matured plants were randomly selected and divided into the four treatments, consisting of two replicates each, with the various treatment plants receiving different coloured tags (blue, white, yellow and red, respectively). After cutting, the re-grown portions of the fronds were measured (from cut surfaces) weekly for 8 weeks and relative growth rate (RGR) was determined. Results indicated that among the various treatment groups, significant increase ($P < 0.05$) in the frond length after the harvesting was observed at the end of the eight-week experimental period. Kelps harvested by cutting 40 cm from the stipe (T_4) recorded the highest frond length at the end of the period of investigation. However, during the period in which growth of the frond occurred in all treatments, the weekly mean RGR of frond per day was significantly higher ($P < 0.05$) in T_1, than in the other treatments, while it was least in T_4 with values of 3.13 and 1.10 % day$^{-1,}$ respectively at the end of the eight-week growth period. The mean relative growth rates for T_2 and T_3 were 2.54 and 1.34 % day^{-1} respectively. Results from this study are important for the management of *Laminaria pallida* and support the suggestion that non-lethal method of harvesting assures regeneration of kelp. The rapid recovery of kelp fronds in this investigation implies that non-lethal harvesting techniques will lead to sustainable management of the Namibian kelp.

Key words: Seaweeds, Kelp, *Laminaria*, re-growth, recruitment

INTRODUCTION

The Namibian Kelp (*Laminaria pallida*) commonly referred to as the split-fan kelp, belongs to an aquatic group of algae, commonly referred to as seaweeds. *Laminaria pallida* together with other seaweeds found along the Namibian coast are important marine resources due to their numerous uses both as industrial and domestic purposes. Primarily, they are harvested worldwide for the extraction of chemicals that serve as gelling and thickening agents in foods, and for media use in medical and microbiological works [1]. A total of 205 seaweed species have been collected from the Namibian waters [2]. In Namibia, *Laminaria* is one of the most commonly harvested species due to its practical application as a source of alginate and uses in pharmaceuticals and animal feed supplements [1, 3, 4].

Laminaria is endemic to southwestern Africa coastline and grows from a low water mark to a depth of about 25 m in very dense stands of 12 plants m^{-2} in shallow coastal waters [1]. The harvest of seaweeds is likely to increase as more of its product is needed for industrial purposes. Increase in abalone farms will increase the exploitation of seaweeds [5].

Methods of harvesting of kelp are important so as to maintain proper re-growth of the plant after cutting. Laminaria can be harvested by cutting the fronds 2 cm above the stipe every four months; however, there are no other documented scientific reports on methods of harvesting of the kelp (*Laminaria pallida*) along the Namibian coast [1]. In South Africa, there are two methods used in harvesting the fronds of the kelp, *Ecklonia maxima* [5]. In the first method the whole 'head' of the kelp sporophyte is cut off between the bulb at the top of the stipe and the primary blade. This is an easy way of harvesting, but it kills the plant. In the second method, the secondary fronds are cut 20–30 cm from the junction with the primary blade. The latter type of harvesting does not kill the plant, because the meristematic zone at the base of the secondary fronds is unharmed [6]. The fronds continue to grow, and this non-lethal harvesting method ultimately gives yields that are 4 – 5 times higher than the 'lethal' method [6].

The length at which the fronds are cut will ultimately alter the canopy thereby affecting the amount of light penetration to the bottom of the kelp bed. Reports from New Zealand indicated that dense canopy can decrease light penetration by as much as 90% [7]. Low growth in *Laminaria hyperborean* with initial stipe lengths of less than about 40 cm suggested that the presence of canopy-forming plants suppresses growth of understorey plants. This was supported by the high lamina growth rate of understorey plants after removal of the canopy-forming plants [8]. Light and length of exposure on frond elongation in *Laminaria ochroleuca* has been shown to be a very important factor affecting growth under laboratory conditions [9]. Therefore, the amount of dense canopy removed (by cutting fronds as different length) through its effects on light penetration, will affect the relative re-growth rate of sub-canopy kelp plants. It is, therefore, postulated that appropriate harvesting methods (knowing at

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what length to cut the fronds) can be beneficial to those industries extracting alginate from the Namibian kelp, *Laminaria pallida*.

This study investigated the effects of cutting the fronds of *Laminaria pallida* at various lengths on the relative re-growth rate (stipe elongation) in its natural environment along the Namibian coastline. The results will assist in developing a sustainable harvesting plan for the resource.

MATERIALS AND METHODS

Study Site

The experimental field at which the investigation was conducted is the Solitude Point, about 11 km from Henties Bay (22° 09' 10.2" S, 14° 17' 12.5" E) along the Namibian coastline (Fig. 1). The field consists of rocky substrate, ideal for kelp attachment. The *Laminaria pallida* population at the field was homogenous and fairly dense (about 6 plants m^{-2}).The field also allows for favourable working conditions during spring low tides.

Figure 1: Henties Bay showing study site

Experimental design

From the experimental field, a total of eighty (80) matured *Laminaria pallida* (Fig. 2) were randomly selected to avoid any experimental bias. The selected plants were divided into 4 treatments (two replicates per treatment), with each treatment having 10 plants. Enough space was left between the different treatments. Each plant was tagged with each treatment receiving a different coloured tag; blue, white, yellow and red, respectively.

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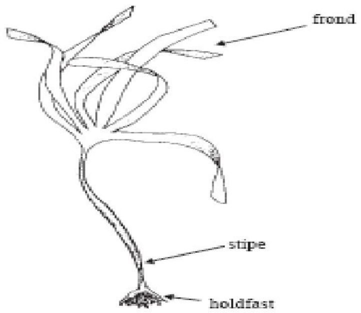

Figure 2: Matured *Laminaria pallida*; adopted from Bianchi *et al*. [1]

The cutting of the fronds at the specified lengths was done during days of low tides using a pair of scissors. The cutting lengths were 0, 15, 30, and 40 cm from the stipe for treatment T_1, T_2, T_3 and T_4, respectively.

Determination of relative growth rate

After cutting, the re-grown portions of the fronds were measured (from cut surfaces) weekly for 8 weeks to the nearest cm. The relative growth rate (RGR, %day^{-1}) for each week was determined following method adopted by Rothman *et al*. [5], using the formula:

$$\mathrm{RGR} = \frac{\ln\left(\frac{l_2}{l_1}\right)}{n} \times 100$$

Equation 1

Where l_2 and l_1 are the final and initial re-grown frond length respectively and n is the number of days.

Statistical analysis

All length measurements for the computation of RGR in this investigation were obtained as mean of ten plants per treatment and recorded mean ± Standard Error (SE). The level of significance between the RGRs for the various treatments were obtained using double factor Analysis of Variance (ANOVA), while the least significant difference (LSD) was used for pair comparison. All levels of significance were determined at 95% confidence interval.

RESULTS

The data obtained at the end of the experimental period indicated that within each treatment group, there were no significant differences ($P > 0.05$) in the frond length during the weekly recording period. However, among the various treatment groups, increases in the frond length of *Laminaria pallida* after the harvesting were observed at the end of the eight-week experimental period were highly significant ($P < 0.05$) (Table 1). Kelps harvested by cutting 40 cm from the stipe (T_4) had the highest frond length of 93.8 cm. This was followed by plants harvested by cutting 30 cm from the

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stipe (T_2) and 15 cm from the stipe (T_3) with frond length of 85.2 and 74.0 cm, respectively (Fig. 3). Statistical analysis indicated that the final length of fronds for T_4 were significantly higher than values recorded for T_1 and T_3 ($P < 0.05$). However, during the period which growth of frond occurred in all treatments, the weekly mean RGR of frond per day was significantly higher ($P < 0.05$) in T_1 (cutting at 0 cm from the stipe), than in the other treatments (Table 2). It was least in T_4 with values of 3.13 and 1.10 %day$^{-1,}$ respectively at the end of the eight-week growth period. The mean relative growth rates for T_2 and T_3 were 2.54 and 1.34 % day$^{-1,}$ respectively.

Results obtained showed that for the first six weeks after harvesting, there was no growth observed in the fronds of T_1 and this treatment recorded the least frond length at the end of the experimental period. The mean increase in frond length recorded for Week 7 was 7.5 cm whereas for Week 8 it was 14.7 cm (Fig. 4). This shows an increase which is almost twice the mean weekly growth recorded for Week 7.

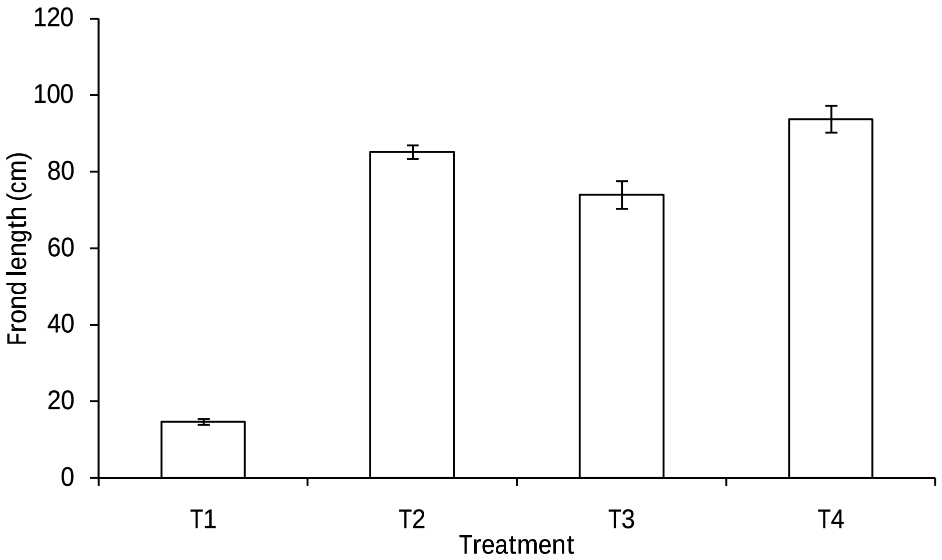

Figure 3: Final frond length at the end of experimental period

The results obtained for T_2 indicated a tremendous increase in frond length as the research period for re-growth increases (Fig. 4). The increase in the mean weekly growth rate between Week 7 and Week 8 was the most as compared to the others. There was a significant difference ($P < 0.05$) between the weeks from the initial week to the final week, with a linear increase in the weekly growth rates from week 1 all the way to week 8. From the result obtained, weekly increase in frond length for T_3 showed an increase in the frond length for the 8 weeks, where a linear increase was observed from the initial week to the final week (Fig. 4). Looking at the mean weekly increase in frond length, there was a tremendous increase, which indicated a significant difference ($P < 0.05$) between the weeks. The mean weekly increase in

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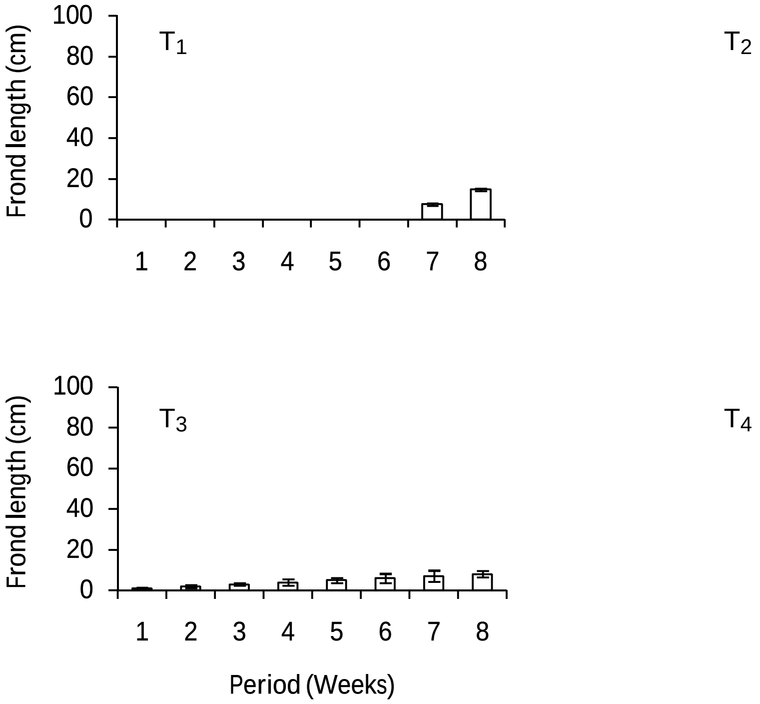
frond length between Week 6 and Week 7 increased the most, by an average of about 17.2 cm.

The results obtained for T_4, showed an increase in the weekly increase in frond length, with the largest increase in the weekly increase in frond length observed between Week 1 and Week 2, with an average increase of about 13.94 cm (Fig. 4).

The weekly mean relative growth rate of T_2, though appreciable during the first and second week, the pattern fluctuated considerably with the lowest values of 1.74 and 1.73 % day^{-1} for week 3 and 6, respectively. Similar fluctuations were recorded for T_3 and T_4 (Fig. 5).



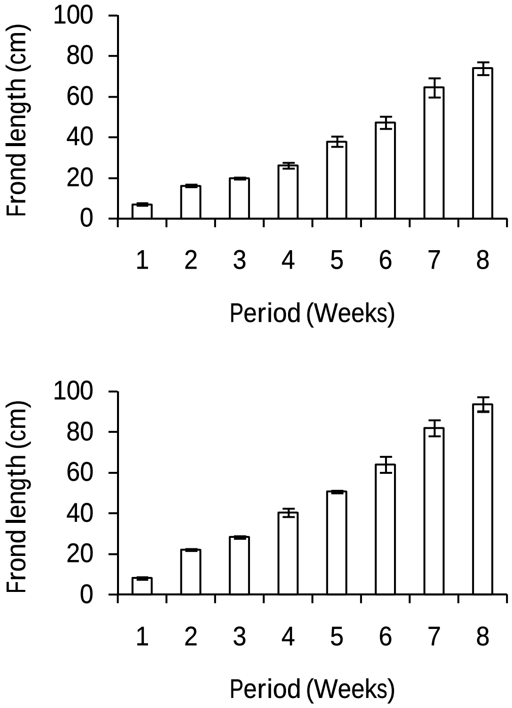


Figure 4: Comparison of mean weekly increase in frond length for all treatments

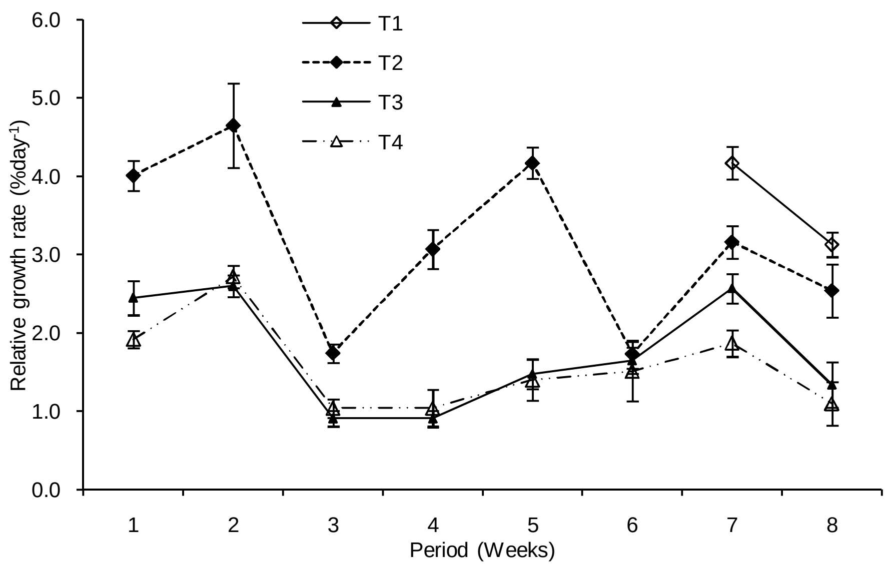


Figure 5: Fluctuations in the mean weekly relative growth rate of frond length of *Laminaria pallida* after harvesting during the experimental period

DICUSSION

Results obtained from this investigation indicated that the Namibian Kelp can be harvested within any length along the fronds, right from the base of the frond to the distal portion. For management purposes, harvesting by cutting from portions of the frond rather than uprooting/trawling of the entire kelp is more ecologically friendly as the epiphytes and holdfast fauna attached to the plants are not lost. Similarly, this type of harvest is non-lethal when compared to uprooting of the kelp. The detrimental effects of complete removal of the kelp plant have earlier been documented [10]. These authors reported that after harvesting of *Laminaria hyperborea* by trawling, though the young kelps grew up rapidly to replace the mature sporophytes, the epiphytes and holdfast fauna populations took significantly longer to recover. The non-lethal harvesting method of the South African kelp, *Ecklonia maxima* has the least ecological effect on epiphytes [11]. Similar results were also obtained in the harvest of other seaweed species, *Macroscystis purifera,* which also did not show significant ecological effect, although for other species like *Eucheuma incinatum* the effect seems major [12, 13]. These differences may be attributed to harvesting methods and the seaweed life history peculiarities.

Results also indicated that harvesting at the base of the fronds will not kill that plant. It is therefore postulated that harvesting of *Laminaria pallida* at the base of the fronds does no harm to the meristematic zone as associated with certain higher plants; as evident from the results obtained in both the weekly and relative growth rate of T_1 (where harvesting was done at the base). In the same vein, earlier investigations have showed that this type of harvesting does not harm the meristematic zone in *Ecklonia maxima* [5, 6]. However, it should be noted that recruitment (stipe elongation) was delayed when harvesting was done at the base.

Contrary to the hypothesis of this study, removal of either the whole surface canopy (T_1) or only distal portions of the secondary fronds (T_2) had no effect on rate of growth (stipe elongation) of sub-canopy kelps despite increase in bottom irradiance after harvesting in T_1. This investigation considered this to show that growth is limited by a factor other than light in this kelp bed.

The findings of study are important for the management of *Laminaria pallida* and support the suggestion that the non-lethal method of harvesting assures the regeneration of kelp. This rapid recovery of the kelp means that other physiological collections, experiments and exploitation of *L. pallida* for commercial purposes can be safely carried out, provided that proper harvesting methods are applied.

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Table 1:Mean weekly frond length* of *Laminaria pallida* after harvesting during the experimental period

Period (Weeks)	Treatments T_1	T_2	T_3	T_4
1	0	5.8 (0.39)	7.1 (0.71)	8.3 (0.49)
2	0	14.9 (0.77)	16.2 (0.64)	22.2 (0.46)
3	0	19.1 (0.68)	19.8 (0.55)	28.4 (0.60)
4	0	28.1 (1.64)	26.3 (1.55)	40.6 (2.09)
5	0	43.5 (1.46)	37.9 (2.82)	50.8 (0.49)
6	0	51.6 (2.52)	47.3 (3.42)	64.1 (3.94)
7	7.5 (0.65)	68.8 (3.14)	64.5 (5.16)	82.0 (3.94)
8	14.7 (0.75)	85.2 (1.78)	74.0 (3.57)	93.8 (3.48)

* Values in parenthesis are standard error (SE) of mean values (n = 10 per treatment)

ANOVA Table

Source of Variation	SS	df	MS	F	P-value	F crit (p=0.05)	F crit (p=0.01)	F crit (p=0.001)
Weeks	12782.210	7	1826.031	13.408	1.78×10^{-6}	2.4875	3.6396	5.5571
Treatments	9654.203	3	3218.068	23.629	6.25×10^{-7}	3.0725	4.8740	7.9383
Error	2859.969	21	136.189					
Total	25296.382	31						

Table 2: Mean weekly relative growth rate of frond length* of *Laminaria pallida* after harvesting during the experimental period

Period (Weeks)	Treatments T_1	T_2	T_3	T_4
1	0	4.01 (0.19)	2.45 (0.22)	1.92 (0.11)
2	0	4.65 (0.54)	2.60 (0.14)	2.72 (0.14)
3	0	1.74 (0.12)	0.91 (0.10)	1.04 (0.12)
4	0	3.07 (0.25)	0.91 (0.10)	1.78 (0.24)
5	0	4.17 (0.20)	1.48 (0.19)	1.40 (0.26)
6	0	1.73 (0.18)	1.65 (0.17)	1.51 (0.38)
7	4.17 (0.27)	3.16 (0.21)	2.57 (0.19)	1.87 (0.17)
8	3.13 (0.17)	2.54 (0.34)	1.34 (0.29)	1.10 (0.28)

* Values in parenthesis are standard error (SE) of mean values (*n* = 10 per treatment)

ANOVA Table

Source of Variation	SS	df	MS	F	P-value	F crit (p=0.05)	F crit (p=0.01)	F crit (p=0.001)
Weeks	12.505	7	1.786	1.704	0.162	2.488	3.640	5.557
Treatments	20.575	3	6.858	6.543	0.002	3.073	4.874	7.938
Error	22.014	21	1.048					
Total	55.094	31						

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