Appendix 1: Biological Information

MACROCYSTIS PYRIFERA

Productivity

Macrocystis pyifera is perennial and can reach lengths of 35 m. It is considered to be the world's fastest growing plant with growth rates recorded at 0.5 m per day and 25 m in three months. Growth of this species appears to be temperature and light limited.

McCleneghan & Houk (1985) examined the impact of canopy removal on holdfast growth in *M.pyrifera* in California and concluded that kelp canopy removal can slow holdfast growth, an impact that was still apparent six weeks following harvest. However, Barilotti *et al*. (1985) found no effects of harvesting on plant survivorship.

Small scale harvesting experiments carried out in Akaroa Harbour showed that "harvesting canopy biomass had no measurable effect on *Macrocystis* plants, and the dominant understorey species" (Pirker *et al*. 2000).

Sustainability Indicators

Maximum biomass of *Macrocystis* occurs in the winter months (Cummack 1980, Pirker *et al.* 2000). Pirker *et al.* noted that marked differences can exist in the demography of *Macrocystis* at a spatial scale of only a few kilometres – and that beds decline and regenerate at different times. In the Akaroa Harbour sites studied, they concluded that no one forest is capable of supporting the removal of consistent amounts of canopy, although two harvests could be sustained per year – one in late spring/early summer just prior to frond senescence and then another cut in late autumn/early winter.

Pirker *et al.* (2000) concluded that sustainable harvest of *Macrocystis* is possible in New Zealand using similar strategies to those employed by the State of California for the *Macrocystis* beds there. They considered that a combination of aerial photography and *in situ* measurements provide an easy method for assessing canopy biomass. They caution, however, that high levels of annual variation in canopy biomass, within and between forests, necessitates the need for annual stock assessments at a population scale until a better understanding of variability is reached. Pirker *et al.* provide detailed options for harvesting strategies for the Banks Peninsula sites studies. They also consider that harvesting of other *Macrocystis* forests should not be allowed before stock assessment surveys have been carried out.

LESSONIA SPECIES

Productivity

No data are available for *Lessonia* on the age of first reproductive maturity (of sporophytes), the reproductive output of individuals, or the longevity of sporophytes. There is also no information available on the responses of populations to removal of adults from the canopy either through harvesting or through storm impacts. It is also not known how removal of blades without removal of holdfasts influences growth and survival of the remaining plant. The meristem in *Lessonia* spp.

is located at the base of each blade immediately adjacent to the junction with the stipe. If the meristem is removed, the stipe is not able to regenerate a new blade. If the distal end of the blade is removed, the meristem is able to continue functioning.

Sustainability Indicators

Lessonia spp. grows on exposed coasts and are predominantly subtidal. Because of the patchy distribution of these species there is potential for over-harvest and resource damage, unless a locally focused management regime is in place.

Management of *Lessonia* as a single stock (i.e. *L.variegata*) is possible around mainland New Zealand. If intensive removal of attached *Lessonia* thalli is undertaken it would be important to know about the impacts of harvesting on survival of individuals (if regrowth is the intention) or on the capacity for recruitment. This would require quantitative and seasonal field observations on biomass, productivity, distribution, reproduction and a recognition that these may differ in different regions within New Zealand.

DURVILLAEA ANTARCTICA

Productivity

In New Zealand, reproduction of *Durvillaea* spp is from late autumn to early spring (April to September), with peak fertility in June-July (Hay 1994).

Large *D.antarctica* thalli may be 10 years old but more typically are 5-8 years. The life span of *D.willana* is longer; although the rigid stipe of this species is more vulnerable to snapping in severe storms, the holdfast of this species is not affected by burrowing animals, as occurs in *D.antarctica.*

Hay (1994) summarises information available on growth rates in *Durvillaea.* Individual growth rates of *D.antarctica* and *D.willana* are highly variable. There is an inverse relationship between relative growth and plant size. In winter months tissue may erode more rapidly than it is produced. Growth rates for *D.antarctica* are fastest during late spring and summer, that is, after the reproductive period.

Harvest trials of *Durvillaea* spp. revealed that, in order to allow recruitment of new thalli, attached thalli should only be harvested in winter during the fertile period. Harvests outside this time resulted in many competing species replacing *Durvillaea* spp. and the *Durvillaea* populations did not recover or return to pre-harvest biomass for some years (Hay & South 1979). These harvest experiments also showed that the whole thalli, including holdfasts, need to be removed as the holdfasts take a considerable time to rot and the presence of the dead holdfasts prevents resettlement of new *Durvillaea* thalli.

Sustainability Indicators

Hay & South (1979) studied the impacts of harvesting in different seasons on the recruitment and recolonisation of *D.antarctica* and *D.willana* populations. They concluded that year round harvesting would result in depletion of the resource as season is critically important to recolonisation. They recommended that harvesting should only occur during the winter. This is the fertile period for *Durvillaea* spp. (May to September for *D.antarctica* and June to October for *D.willana*), and thus is when zygotes are being produced and able to settle and re-establish.

PORPHYRA SPECIES

Productivity

Species of *Porphyra* are considered to display some of the most complex life histories known in the algae. Data on age and growth are species specific and there are few data available. Although a study on growth and reproduction of *Porphyra* was carried out at three sites in southern New Zealand (Brown et al. 1990), it is now recognised that multiple species occur at each of these sites and, thus, the data do not contribute to an understanding of growth and age for any particular species.

Sustainability Indicators

A study was carried out in the Kaikoura area in the 1980s to examine harvest method and timing, and the impact of previous harvesting on yield and regeneration (Nelson & Conroy 1989, Nelson *et al.* 1990). The method of harvest was found to have a major effect on the extent of regeneration: where basal tissue was left, thalli were able to be harvested again in two months whereas complete removal of thalli saw very little new recruitment and growth. This study did show that if harvesting is carried out in such a way as to leave basal material, regeneration occurs rapidly and thus, multiple harvests can occur.

Previous examinations of the populations at Kaikoura suggested that there are significant inter-annual variations in the biomass and local distribution of *Porphyra* spp. at Kaikoura. This variability has since been observed around the country with a range of species.

The harvest of *Porphyra* spp. around Kaikoura has been operating sustainably for more than 15 years. It is important that the management regime for this resource recognises the regional characteristics (for example in the species present, the timing of growth and fertility with temperature) as well as site-specific features. Seasonal and inter-annual variation in population size and growth mean that caution is required when setting harvest limits.

Management of a genus as a single stock is problematic given that the genus includes up to 35 species. There are no data available that would provide a biogeographic or species-defined basis for decision making: there is no information about standing stock, productivity, seasonality of growth for any species or group of species.

Management at a population level is limited also by the absence of data, but in the short-term would be the most effective approach to decisions on resource access and quantities to be harvested. This would require quantitative field observations on biomass, productivity, distribution, and seasonality.

GRACILARIA CHILENSIS

Productivity

It is not possible to generalise about species-specific characteristics. Laing *et al*. (1989) grew *G. chilensis* in culture, examining the influence of temperature, light and nitrogen on growth. Laboratory experiments on *G. chilensis* and *G. truncata* gave relative growth rates of 5-8% per day for *G. chilensis* and 2-4 % per day for *G. truncata* for 5 weeks in culture, with *G.truncata* becoming necrotic after this point (Pickering *et al.* 1993). Growth is faster for *G.chilensis* in summer and late autumn, increasing with temperature from 10-25ºC (Terzaghi *et al*. 1987).

Sustainability Indicators

As part of autecological studies, Nelson (1989) and Pickering *et al*. (1990) presented data on the biomass of *G.chilensis* from the Wellington region and Invercargill, respectively. A series of reports produced in 1980s on the potential for aquaculture of *Gracilaria* (Nelson *et al.* 1986, Terzaghi *et al*. 1987) estimated a production rate of ca. 30 T/hectare of *G.chilensis*. These estimates in part were based on data from the studies carried out at the Auckland Regional Authority Manukau Sewage Purification Works. Adjacent to this area there were very extensive beds of *Gracilaria,* which were considered to be a result of the high nutrient levels in the effluent from the Works. During the 1980s there were various attempts to harvest the *Gracilaria* in these beds. In the past two years, the oxidation ponds in the Manukau have been dismantled and the area where the *Gracilaria* beds once were found is now substantially physically altered. There are still extensive beds of *Gracilaria* in other parts of the Manukau Harbour, although the relative proportions of the two terete *Gracilaria* species is unknown.

Management of this genus as a single stock is problematic given that *Gracilari*a in mainland New Zealand includes at least four species with commercial potential, occupying different habitats. In the past, *G.chilensis* has been regarded as the species with the most significant commercial potential, both as an agarophyte and as a species that can be used to feed farmed paua. There is a major problem, however, resulting from the recent discovery of the cryptic species in the Manukau Harbour, as it apparently grows alongside *G.chilensis*, occupying a similar ecological niche. There are no data available on how, or if, the productivity and growth of these species differ. Although a number of studies have been carried out in the Manukau, the stocks there were treated as a single species and, thus, there must be questions about the reliability of these data.

Because of the patchy distribution of all species of *Gracilaria,* there is potential for over-harvest and resource damage unless a locally focused management regime is in place.

Management at a population level is limited by the absence of data for most sites but, in the short-term, would be the most effective approach on which to base decisions on resource access and quantities to be harvested. This would require quantitative field observations on biomass, productivity, distribution, and seasonality. Although the polysaccharide agar does not appear to differ between life history phases, it is not known how each phase contributes to the reproduction/population stability. Research is required to determine if harvesting regimes and management approaches need to take this into account.

ECKLONIA RADIATA

Productivity

Biomass, plant size and plant density vary with locality and depth, with the maximum biomass (3.6 +/- 0.2kg.m^{-2}) and plant density (15.6 +/- 0.5 m^{-2}) recorded by Trenery at 7 m depth. Mean thallus size was greatest at deepest sites.

Ecklonia may be harvested for biomass or for its constituent compounds. Schiel & Nelson (1990) recommend that harvesting should occur in the winter-spring. Yields of extractable compounds such as alginate, mannitol, and laminarin, however, vary seasonally (Trenery 1985), and there may be pressure for harvests to occur at times that maximise yields of these compounds. For example, yields of alginate in April are 1.5 times that obtained in September, and yields of laminarin in May ten times that obtained in September.

Because of the logistic difficulties in collecting attached stipitate laminarians such as *Ecklonia*, large scale hand collection seems unlikely unless there is a high value product associated. If SCUBA or dredge equipment is used then it is critical that only relatively small patches of *Ecklonia* are removed in order to assure recolonisation, and to minimise negative harvest impacts on associated fauna and flora.

Within the past 15 years there have been several episodes of mass die back of *Ecklonia* in north eastern New Zealand (e.g. Cole & Babcock 1996).

Sustainability Indicators

The fertility of thalli and the appearance of recruits are seasonal. *Ecklonia* is winter fertile and in the north-eastern North Island shallow populations have sori from May to November (Novaczek 1984b) and recruits appear from September to late December (Schiel 1981). Schiel observed that recruitment in *Ecklonia* is temporally limited and closely linked to reproductive periodicity suggesting that the microscopic phase does not remain viable for very long. He also observed a spatial element to recruitment success, as canopy species are the ones most likely to recruit into cleared patches. Schiel (1981) found that in the north-eastern North Island, 75% of recruits of *Ecklonia radiata* occurred within 8 m distance from adult thalli.

Adult *Ecklonia* thalli can be large and as few as 20 adult thalli per m^2 may form a closed canopy (Trenery 1985). In north-eastern New Zealand thalli from depths 2-7 m have high lamina growth rates (5.4 +/- 0.4 cm per month) during December and January whereas at 15m depth in the same period growth rates were lower and differences between sites were apparent (Trenery 1985). Wave action at shallow sites reduces lamina length. In areas that have been harvested, recruitment, growth and survival were much greater than in control plots except at very shallow depths.

High light intensity inhibits the growth of recruits and/or enables other algal species to take over the available space (Trenery 1985, Schiel 1988). In southern New Zealand, in Doubtful Sound, Miller (pers.comm.) has recorded growth rates of 0.06-0.45 cm d^{-1}, with a temporal pattern of high growth rate from September to February, low rates from April through to June, with increases beginning again in August. Miller found significant inter-annual variation in the timing and amount of growth recorded. Low inorganic nitrogen concentrations in the seawater and C:N ratios indicate that in Doubtful Sound, *E.radiata* is N-limited year round. Density of individuals is also low in Fiordland with 2.5-10 thalli m^{-2} (Miller pers. comm.).

The importance of *Ecklonia radiata* to marine communities is well documented and the phenology of this species indicates that the ecological consequences of harvesting could be significant (Schiel 1988, Schiel & Nelson 1990 and authors therein). Jones (1984, 1988) showed that reef fishes such as wrasses and monocanthids recruit, some exclusively, among the fronds of *E.radiata* and feed exclusively on small invertebrates there. Choat & Ayling (1987) showed that the presence of *Ecklonia* beds affects the character of the fish fauna throughout northern New Zealand. Sea urchins do not recruit or survive well as juveniles in *Ecklonia* beds (Andrew & Choat 1985). When *Ecklonia* canopy was removed in summer, *Sargassum* and *Carpophyllum* species recruited first, although *Ecklonia* recruited 6-9 months later. Should we use some of this paragraph in Habitats of significance?

PTEROCLADIA SPP.

Productivity

There are two species of *Pterocladia* in New Zealand, *P.lucida* and *P.capillacea*.

P.lucida is frequently found to be fertile whereas reproductive structures are rarely found on *P capillacea*.

Gerring *et al* (2001) found that thalli of *P.lucida* harvested in summer, either by plucking or by cutting, recovered to their initial biomass within 12 months, whereas when harvested in winter, the cut and the plucked thalli remained smaller than the control thalli and did not recover biomass within a year. They concluded that sustainable harvest of the resource was possible if the removal occurred in summer – but cautioned that this conclusion needed to be tested at larger physical scales, over longer time periods and at other sites.

Sustainability Indicators

McCormick (1990) found that biomass of *P.lucida* at Leigh was highly variable along and down the reef. Much of the variation was explained by differences between depths although there was even greater variation between quadrats. Thus, although there was a general trend with depth, there was very significant patchiness in distribution. This contrasts with the pattern of distribution found at Ngawihi where much of the variability in *P.lucida* biomass was attributable to differences between quadrats and there was no depth trend found in the biomass data. McCormick considered that these differences were, at least in part, attributable to the differing reef topography with steeply sloping short reef structure at Leigh and long and gradually sloping reefs on the Wairarapa coast at Ngawihi. These differences in topography will affect the influence of wave exposure and light penetration - two key environmental factors influencing macroalgal distribution.

Although various figures have been published describing the *Pterocladia* resources, these estimates are very locally focused and somewhat difficult to compare. Luxton & Courtney (1987) stated relatively small areas have sustainable yields in excess of 10t dry wt/yr. McCormick (1990) gave a standing crop estimate for a 3 km stretch of coast in north eastern North Island as between 25,336 kg and 32,980 kg depending on which method was used for surveying the populations. Gerring *et al* (2001) recorded 146-200 wet weight t in a 436,556m^2 area sampled in summer autumn and a winter biomass of 119-121 wet weight t for the same area. They converted this to an estimated figure of 173 t wet weight over the 4.4km of coastline studied.

Gerring et al (2001) cautioned that there is likely to be significant inter-annual variability in the abundance of P. lucida and that this limits the extent to which results from a specific site/time can be generalised to other places and times.

Populations of *P.lucida* and *P.capillacea* have been sustainably harvested for more than 60 years. Because of the patchy distribution of these species, there is potential for over-harvest and resource damage in these areas where hand-picking predominates as the collection method, unless a locally focused management regime is in place.

Management of these two species as a single stock is problematic given that they occupy different habitats, and relatively little is known about *P.capillacea* in New Zealand. Management at a population level is limited also by the absence of data but, in the short-term, would be the most effective approach to decisions on resource access and quantities to be harvested. This would require quantitative field observations on biomass, productivity, distribution and seasonality.

Appendix 2 – Beach-Cast Seaweed Commercial Harvest Areas

Under the Fisheries (Beach Cast Seaweed Area Prohibition Notice) 2005, permit holders may only take beach-cast seaweeds from the areas set out below:

FMA 1[3]

(i) The 'coastal area'[4] between Blackney Point, Rangaunu Bay (approximately 34º52.8'S and 173º17.7'E) and the eastern end of Coopers Beach, Doubtless Bay (approximately 34º59.2'S and 173º31.0'E).

(ii) The 'coastal area' between Marsden Point (approximately 35º50.8'S and 174º29.8'E) and Pakiri River, north of Leigh (approximately 36º15.6'S and 174º43.3'E).

(iii) The 'coastal area' between Orere Point (approximately 36º57.7'S and 175º15.0'E) and Kaiaua (approximately 37º06.8'S and 175º18.1'E), on the western side of the Firth of Thames.

(iv) The 'coastal area' between Tararu (approximately 37º06.8'S and 175º30.9'E) and Cape Runaway (approximately 37º32.3'S and 177º59.0'E), excluding Colville Bay, Coromandel Harbour, Manaia Harbour, and Te Kōuma Harbour, Ohiwa Harbour, Maketu Estuary, Waihi Estuary, and within 1 kilometre of the banks of Whakatane River, Waiotahi River, and Waioeka River.

FMA 2

(i) The 'coastal area' between Tuaheni Point (near Gisborne) and Cape Runaway.

(ii) The 'coastal area' between Mataikona River (approximately 40º47.1'S and 176º16.1'E) and Turakirae Head (approximately 41º26.5'S and 174º55.1'E), excluding within 1 kilometre of Onoke Spit, Cape Palliser, Castle Point and Te Aro Huruhuru.

FMA 3

(i) The 'coastal area' between Haumuri Bluffs (approximately 42º33.9'S and 173º30.3'E) and the Waipara River (approximately 43º09.2'S and 172º48.1'E).

(ii) The 'coastal area' between Akaroa Head and the Waitaki River (approximately 44º56.3'S and 171º08.9'E), excluding within 1 kilometre of the banks of Ashburton River, Rangitata River, Washdyke Lagoon and Wainono Lagoon.

(iii) The 'coastal area' between Cape Wanbrow (approximately 45º07.7'S and 170º58.8'E) and Shag Point (approximately 45º27.9'S and 170º49.2'E).

FMA 5

(i) The 'coastal area' between Waimatuku Stream, east of Riverton (approximately 46º22.1'S and 168º09.8'E) and the Waiau River, Te Waewae Bay (approximately 46º11.8'S and 167º37.3'E).

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[3] Fisheries Management Area 1

[4] 'Coastal area' includes but is not confined to the littoral and intertidal zone.

(ii) The ‘coastal area’ between Ackers Point, Stewart Island (approximately 46º53.8'S and 168º09.8'E) and Lee Bay, Stewart Island (approximately 46º51.3'S and 168º07.7'E).

FMA 7

(i) The ‘coastal area’ between French Pass and Clarence River (South Marlborough Sounds).

FMA 9

The ‘coastal area’ between the northern end of Kahokawa Beach (at 34°31.6'S and 172°43.5'E) and Tirua Point (approximately 38º23.2'S and 174º37.9'E) excluding Whangape Harbour, Herekino Harbour, Hokianga Harbour, Kaipara Harbour, Raglan Harbour, Aotea Harbour, Kawhia Harbour and within 1 kilometre of the banks of the Waikato River.