Journal of Applied Phycology (2006) 18: 323–334
DOI: 10.1007/s10811-006-9029-7

A remote sensing approach to estimating harvestable kelp biomass

M. S. Stekoll[1,*], L. E. Deysher[2] & M. Hess[2]
[1]*Department of Natural Sciences, University of Alaska SE, 11120 Glacier Highway, Juneau, AK 99801 USA;*
[2]*Ocean Imaging, 201 Lomas Santa Fe Drive, Suite 370, Solana Beach, CA 92075*

*Author for correspondence: e-mail: ffmss@uaf.edu; phone: 1-907-465-6279

Key words: kelp mapping, remote sensing, biomass, kelp management, kelp canopy, *Nereocystis*

Abstract

Regulations of the Alaska Department of Fish and Game require that all fisheries in the state have a harvest management plan. In southeast Alaska two species of floating kelps, *Nereocystis luetkeana* and *Alaria fistulosa*, have been commercially harvested since 1992 for use as agrochemicals by the Alaska Kelp Company. However, there is currently no harvest management plan for this fishery. The lack of a formalized management plan is one factor that has kept the kelp industry from expanding in the state. We have employed an aerial digital multispectral imaging system (DMSC) calibrated with ground truthing for performing such an assessment. The system can be flown at varying altitudes to achieve spatial resolutions ranging from 0.5 to 2 m. Rapid ground truthing techniques were developed using morphometric measurements to predict biomass. Analysis of the DMSC imagery showed that good correlations could be developed between the multispectral imagery and kelp biomass estimates collected at the ground-truth sites. Repeatable estimates of kelp bed area derived from the multispectral imagery could be made at varying tidal levels. However, broad scale maps of kelp biomass suitable for estimating harvest rates could not be made at different tide levels. Multispectral imagery suitable for this purpose must be collected at a standard tidal level.

Introduction

Kelp beds with floating canopies cover much of the near shore ocean surface along the West Coast of North America (Foster & Schiel, 1985). There are major beds of these kelps in the Alexander Archipelago of southeast Alaska. A survey of floating kelps in southeast Alaska in the early 1900's found over 100 separate beds containing an estimated seven million metric tons of plant biomass. The majority of the plants were *Nereocystis luetkeana* (Mertens) Postels *et* Ruprecht with *Alaria fistulosa* Postels *et* Ruprecht and *Macrocystis* sp. making up the remainder (Frye, 1915). Subsequent surveys have confirmed the locations and area extent of these beds, but have noted that the dominant species making up the beds has changed since 1915 (van Tamelen & Woodby, 2001). Current accurate estimates of kelp biomass are lacking at this time. Although selected areas of *Macrocystis* have been surveyed in southeast Alaska (van Tamelen & Woodby, 2001) there has been no survey done for *Nereocystis* since 1915.

There are currently two commercial uses for floating kelps in Alaska. The giant kelp, *Macrocystis*, is harvested in southeast, south-central and western Alaska, mainly for the commercial herring roe-on-kelp harvest (Stekoll, 1998). In addition, in southeast Alaska the two other species of floating kelps, *N. luetkeana* and *A. fistulosa*, have been commercially harvested since 1992 for use as agrochemicals. The major harvester of this resource is the Alaska Kelp Company (formerly Pacific Mariculture Company, Inc.) which processes the seaweeds for use as a plant fertilizer supplement. The product (formerly sold as OptiCrop and now as Alaska Kelp or Garden Grog) is used in various agricultural and horticultural applications and has enjoyed moderate commercial success.

In order to ensure the sustainability of *Nereocystis* harvesting, it is necessary to develop a stock assessment

method for management of the kelps. Because resource managers normally use estimated biomass to regulate harvests, the key to the harvest management plan is the ability to determine the biomass of the kelp beds. However, estimation of the biomass of floating kelps is problematic with respect to time and expense needed for accurate estimates. The Alaska Department of Fish & Game is currently considering management of these beds using the area covered by the kelp canopy (van Tamelen & Woodby, 2001).

Mapping of kelp beds by remote sensing has primarily used near-infrared aerial photography for delineating surface canopy area. Aerial photography has been used in Canada (Foreman, 1975) and for over 30 years to map the *Macrocystis pyrifera* canopies in California (North et al., 1993). This method is used for determining kelp bed lease data by the California Department of Fish and Game. SPOT satellite imagery was found to be useful for estimating the biomass of floating canopies of *M. pyrifera* (Belsher & Mouchot, 1992). However, work on *Macrocystis* beds in California has shown that only the largest beds in this region can be effectively mapped due to the 20-meter spatial resolution currently available with the SPOT multispectral sensor (Deysher, 1993). The kelp beds in Alaska are comparable to the small and medium sized beds in California. A spatial resolution finer than 20 m is required to quantify the biomass of these beds. In addition, kelp beds in Alaska can be composed of three different kelp species. Kelp monitoring surveys in Washington State using a multispectral imaging system found that a 4 m spatial resolution was not sufficient to distinguish *Macrocystis* from *Nereocystis*.

The research described here addresses the biomass and area assessment aspect of a kelp harvest management plan. The objective of our research was to develop a reliable and cost effective method for estimating the area and biomass of the two species of kelps (*Nereocystis luetkeana*, and *Alaria fistulosa*) in southeast Alaska that have potential for a viable fishery

Methods

Site selection

The study area was a harvest area used by the Alaska Kelp Company. The site lies north of Pt Baker at the south end of Keku Strait along the southwest coast of Kupreanof Island (Figure 1) at approximately 133 °24′W and 56 °29′N. The study area consisted of approximately 20 distinct kelp bed areas that ranged in size from 0.2 to 12 hectares. Many of the beds fringe the small islands and shallower reefs in the area and comprise mainly *A. fistulosa. Nereocystis* was found on the outside of the *Alaria* beds and on reefs with more wave exposure and current flow.

Ground truthing

In 2002 seven separate kelp beds in the permitted harvest area north of Pt Baker were selected and classified by their estimated kelp densities. A surface buoy was anchored in the middle of the each of the selected sites. Scuba divers swam transects of 20 to 40 m parallel with the outer edge of the kelp canopy, starting at the buoy anchor. Density counts were taken with 1 m square quadrats placed every 4 m along the transect. All *Nereocystis* and *Alaria* were counted. Several *Nereocystis* plants (thalli) to represent all sizes of plants were haphazardly selected near each transect and taken back to Pt Baker for morphometric measurements. In order to determine the consistency of the morphometric correlations from more distant sites, we also collected about 90 *Nereocystis* plants near Juneau, Alaska. Fresh weight was determined for each plant along with the same suite of measurements made on the plants near Pt Baker.

The following measurements were taken on individual plants collected from sites near Pt Baker and in Juneau in the summer of 2002.

Stipe length: measured from the holdfast to the top of the bulb (pneumatocyst).
Blade length: measured from the top of bulb to the end of longest blade.
Bulb diameter: the outside diameter of the bulb.
Sub-bulb diameter: the diameter of the stipe 15 cm below the bottom of the bulb.
Blade weight: the fresh weight of all of the blades.
Total weight: the fresh weight of the blades, stipe and bulb.

Based on correlation results from 2002, in 2003 only the bulb and sub-bulb diameter and the total fresh weight were measured.

In 2003 the density counts were performed by preselecting eight sites of varying density from beds in the study site. The center of each of the selected density sites was marked with a buoy. At the surface four sets of two floating quadrats (0.5×2.0 m) were placed orthogonal to each other ("+" shape), centered on the