

SPATIAL AND TEMPORAL DISTRIBUTION OF THE CRINOID *FLOROMETRA*
SERRATISSIMA ON THE OREGON CONTINENTAL SHELF

BY

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To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of NOELANI
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Chair

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Abstract

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Filter-feeders in deep-sea and continental shelf environments form dense aggregations that create structural habitat and modify the benthic environment. Researchers working on Heceta Bank, an important commercial fishery area, used both biotic and abiotic factors to define habitat by integrating the mega-faunal invertebrate community with the physical substrate. This research recognized that groundfish and invertebrates are part of continental shelf communities and that a community approach provides a more realistic resolution of habitat. One important community identified during this research consisted of ridge and boulder habitat where juvenile rockfish, and the crinoid *Florometra serratissima*, were particularly abundant.

My research focused on examining spatial, temporal and size variation in *Florometra* on Heceta Bank. The remotely operated vehicle ROPOS surveyed 9 and 13 stations on Heceta Bank in the summers of 2000 and 2001, respectively. I reviewed all videotapes from ROPOS and delineated habitat patches, within which I calculated the density of crinoids. *Florometra* was most abundant on ridge and boulder habitats, with an average density of

18,919 ha. There was a significant decrease in abundance between 2000 and 2001 and a significant increase in density at night. The highest abundance was observed on the shallow, southern bank top and decreased into the deeper, muddier stations. Crinoid size showed a positively skewed distribution and there was no correlation between size, bottom type and density.

Florometra aggregations may serve as an indicator of the local hydrodynamics, with individuals occurring over a broad depth range, in multiple habitats and varying over time. The presence of juvenile fish in ridge and boulder habitats on Heceta Bank may be due to the abundance of vertical relief and food sources provided by commensal organisms associated with these large aggregations of crinoids. My investigation highlights the importance of mega-faunal invertebrate aggregations on the community structure of benthic continental shelf ecosystems and the integral role these populations play in defining habitat.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
ABSTRACT.....	iv
LIST OF TABLES	viii
LIST OF FIGURES	ix
CHAPTER	
1. INTRODUCTION	
a. Habitat.....	1
b. Heceta Bank community.....	3
c. Crinoid ecology.....	4
d. Objectives	5
2. RESEARCH DESIGN AND METHODOLOGY	
a. Submersible methodology	5
b. Video analysis	6
c. Calculation of density	8
d. Calculation of size.....	8
3. RESULTS	
a. Area and habitat sampled.....	9
b. <i>Florometra</i> density.....	10
c. <i>Florometra</i> size.....	11

4. DISCUSSION	
a. Possible factors important to <i>Florometra</i> distribution.....	12
b. Possible factors important to <i>Florometra</i> temporal variation.....	14
c. Implications for crinoid - fish associations	15
d. Future studies	16
BIBLIOGRAPHY	18
APPENDIX	
A. Summary of all quantitative ROPOS transects completed on Heceta	
Bank, OR, in 2000 and 2001	33
B. Summary of area of bottom types sampled on Heceta Bank, OR, in 2000	
and 2001	34

LIST OF TABLES

1. Model II ANOVA assessing the size variation of <i>Florometra</i> on multiple levels	23
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LIST OF FIGURES

1. Map illustrating the location of Heceta Bank to the coast of Oregon, USA.....	24
2. Photographs illustrating the use of crinoids as shelter by rockfish.....	25
3. Stations surveyed on Heceta Bank, OR, in 2000 and 2001 with transect paths and depths displayed.....	26
4. Percent cover of bottom type on day transects in 2000 and 2001 on Heceta Bank, OR.....	27
5. Percent cover of bottom type on each station with both years pooled.....	28
6. Diurnal variation in mean crinoid density on replicated transects in 2000.....	29
7. Inter-annual crinoid density on daytime transects on Heceta Bank, OR, in 2000 and 2001	30
8. Spatial map of the abundance of crinoids on Heceta Bank, OR, derived from Ordinary Kriging analysis.....	31
9. Length distribution of crinoid arms sampled on Heceta Bank, OR,	32

Spatial and Temporal Distribution of the crinoid *Florometra serratissima* on Heceta Bank

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Abstract: Filter-feeders in deep-sea and continental shelf environments form dense aggregations creating structural habitat and modifying the benthic environment. Researchers working on Heceta Bank, an important commercial fishery area, used both biotic and abiotic factors to define habitat by integrating the mega-faunal invertebrate community with the physical substrate. This paper focuses on an abundant crinoid on Heceta Bank, *Florometra serratissima*, examining its' spatial, temporal and size variation. The remotely operated vehicle ROPOS surveyed 9 and 13 stations on Heceta Bank in the summers of 2000 and 2001, respectively. We reviewed all videotapes from ROPOS and delineated habitat patches, within which we calculated the density of crinoids. *Florometra serratissima* was most abundant on ridge and boulder habitats, with an average density of 18,919 ha⁻¹. There was a significant decrease in abundance between 2000 and 2001 and a significant increase in density at night versus day. The highest abundance was observed on the shallow, southern bank top and decreased into the deeper, muddier stations. Crinoid arm length (size) showed a positively skewed distribution and there was no correlation between size, bottom type and density. *Florometra serratissima* aggregations may serve as an indicator of the local hydrodynamics, with individuals occurring over a broad depth range, in multiple habitats and varying over time. This investigation highlights the importance of mega-faunal invertebrate aggregations on the community structure of benthic continental shelf ecosystems and the integral role these populations play in defining habitat.

Keywords: Crinoid *Florometra serratissima* Habitat Continental-shelf Invertebrate community

INTRODUCTION

Habitat: The management of commercial fisheries on continental shelves is dependent on understanding the distribution and abundance of fish species and their habitat (Auster 2001). While many studies have focused on the physical attributes of benthic habitats, others have begun to focus on the biology of species and the role they serve as habitat. More recently, these factors have been integrated into ecological based habitat management strategies for restoration and sustainability of commercially viable fisheries (Bax et al. 1999, Fogarty 1999, Nasby-Lucas et al. 2002).

Filter-feeders in deep-sea and continental shelf environments may form dense aggregations that create habitat structure and modify the benthic environment (Gill and Coma 1998, Turner et al. 1999, Brodeur 2001). These structures alter the hydrodynamic flow regime, provide refuge from predation, competition, and physical stress, and serve as an important source of food and nursery habitat for fish (Kaiser et al. 2000). It was through the study of commercially important fish species that aggregations of invertebrates in these environments were first identified

(Collie et al. 2000, Kaiser et al. 2000). The co-occurrence of these aggregations with fishes can provide important insights into the definition of fish habitat.

Habitat has a significant effect on the distribution, abundance, and diversity of Pacific Coast groundfish (Pearcy et al. 1989, Stein et al. 1992, Greene et al. 1999, Norse and Watling 1999, Schmitt 1999, Yoklavich et al. 2000). Observations have shown that groundfish use invertebrate assemblages as shelter, however, habitat use is wide and varied (Stein et al. 1992, Yoklavich et al. 2000, Brodeur 2001). Detection of mega-faunal invertebrate populations is not difficult with modern technology, but the nature of the associations within the community can be hard to define (Bax et al. 1999). Once detected the invertebrate aggregations need to be identified in order to incorporate a biotic component into the definition of habitat. Consequently, the ability to quantify habitat using biological communities as well as physical structure will assist in ecological based habitat management.

The importance of habitat to fishery management has found its way into United States law through the Sustainable Fisheries Act (SFA). As a mandate of the SFA, fishery management councils must prepare re-building plans for over-fished species and identify "Essential Fish Habitat" (EFH) for each commercially managed fish stock (Sptel 2000). EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity" (NMFS 1996).

In January of 2000, the Secretary of Commerce announced that the North American West Coast groundfish fishery had collapsed (Sptel 2000). The present EFH for these groundfish includes "all waters from the mean higher high water line, and the upriver extent of saltwater intrusion in river mouths along the coasts of Washington, Oregon and California, seaward to the boundary of the U.S. exclusive economic zone" (Casillas et al. 1998). This definition of EFH encompasses all groundfish because of the lack of data on individual species and the large geographic area (defined by seven broad habitat types) that these species occupy throughout their lifetime. As rockfish species continue to decline it is essential that EFH for each species be defined by the substrate type and invertebrate associations associated with each life stage.

Heceta Bank community: The first major attempt to associate west coast groundfish populations with particular habitats occurred on Heceta Bank, Oregon, in 1987-1990 (Pearcy et al. 1989, Hixon et al. 1991, Stein et al. 1992). Heceta Bank is an important commercial fishing area off the Oregon Coast. Located 55 km offshore, it is the largest rocky reef in the Pacific Northwest being 50 km in length, ranging from 10-20 km in width, and varying from 60 m to > 700 m in depth (Figure 1). Hixon et al. (1991) quantified associations between specific habitats and groups of fishes on Heceta Bank, using replicated manned submersible transects located at six stations on the bank. They defined this habitat using both biotic and abiotic factors by integrating the mega-faunal invertebrate community with the

physical substrate. This research recognized that groundfish and invertebrates form continental shelf communities and that a community approach provided a most realistic resolution of habitat.

Hixon et al. (1991) defined three contrasting benthic communities on Heceta Bank: 1) mud habitat with patches of *Allocentrotus* urchins, 2) ridge and boulder habitat with vase sponges (*Scypha* and *Lophon*), basketstars (*Gorgonocephalus*), and crinoids (*Florometra serratissima*; hereafter referred to as *Florometra*), and 3) a heterogeneous boulder and cobble habitat with crinoids, brittlestars (*Ophiacantha*) and demosponges. Most rockfish formed fairly distinct assemblages in accordance with these three major habitats. In particular, juvenile rockfish, whose habitat was previously unknown, were most abundant in ridge and boulder habitats where they were thought to utilize the crevices and mega-faunal invertebrates as shelter (Hixon et al. 1991). Large aggregations of the crinoid *Florometra* were found on rocky substrates on ridges, boulders, and cobbles in close association with schools of juvenile rockfish (Figure 2). Successful management of juvenile rockfish will thus require an understanding of the association of these fishes with crinoids.

Crinoid ecology: The biology of *Florometra* has been studied in subtidal populations in Canada. *Florometra* is ubiquitous on rocky continental shelf environments from Baja California to subtidal environments in Alaska. *Florometra* is an unstalked (antedonid), microphagous suspension feeder in the Class Comatulid with origins in the Jurassic period (Shaw and Fontaine 1990). It commonly forms large aggregations, thus providing potential habitat for other organisms. Adult crinoid aggregations have been observed in habitats ranging from subtidal reefs to deep-sea benthic habitat (Meyer 1973, Meyer 1985). However, no studies have defined optimal habitat for crinoids. Aggregations are thought to be maintained by gregarious settlement after a pelagic larval stage (Mladenov 1981) and through the enhanced reproductive success of closely spaced broadcast fertilizers (Mladenov and Chia 1983). However, the hydrodynamics of feeding may also have a major effect on sustaining aggregations (Day et al., Meyer 1973, Conan et al. 1981, Gill and Coma 1998). Within a group of aggregating individuals, intermingling arms create local eddies that increase the residence time of particles, aiding in the capture of food (Meyer 1973, La Touche 1978, Gill and Coma 1998). Aggregations may be beneficial to the community because greater numbers of individuals are able to capture food more efficiently.

Sublethal predation on crinoids by fish and crustaceans has been observed (Mladenov 1983, Schneider 1988, Lawrence and Vasquez, Ameziane and Roux 1997) and is thought to have played a major role in the crinoid's ecological evolution (Meyer and Macurda 1977, Macurda and Meyer 1983, Meyer et al. 1984, Nichols 1985). The success of the comatulid has been attributed to its' ability to swim and crawl (Meyer and Macurda 1977) thereby helping it evade predators. Although predation on *Florometra* by asteroids, crustaceans and fishes has been

observed, *Florometra* has not been identified as a significant component of the diet of any of these organisms (Mladenov 1983, Shaw and Fontaine 1990).

Objectives: The goals of this study are to examine spatial and temporal variation in the abundance of *Florometra* at Heceta Bank, OR, while also examining *Florometra* size variation to gain insights into population dynamics. This study provides an example of the integration of several aspects of habitat and crinoid biology as a basis for future management plans for groundfish. Our work was part of a larger project aiming to replicate the historical fish transects originally completed in the late 1980's on Heceta Bank, OR, and to better understand fish – habitat associations.

RESEARCH DESIGN AND METHODOLOGY

Submersible methodology: We investigated *Florometra* with an underwater submersible vehicle using the methodology described by Stein et al. (1992) and Hixon et al. (1991) in order to permit comparisons with these studies. We modified the methodology used by the manned submersible *Delta* in previous studies for use by the remotely operated vehicle ROPOS on the R/V *Ronald H. Brown*. ROPOS resurveyed five of the six stations previously surveyed by Stein et al. (1992; Stations 1-6) and explored new, unique areas based on bathymetry and backscatter maps of Heceta Bank (Stations 7-18; MBARI 2001, Embley et al. in revision) in the summers of 2000 and 2001. A total of nine stations were sampled in 2000 and 13 in 2001 (Figure 3).

Transects were run similar to a Brock fish transect method used by SCUBA divers in shallow water (Stein et al. 1992). ROPOS descended to the seafloor and transited to a pre-determined location. Attempting to maintain a constant height of 1 m from the bottom, ROPOS would then navigate along a known heading, which was pre-set to minimize observer and pilot bias. Transiting at a constant speed of approximately one knot, transects were standardized to two hours in duration. A minimum one half-hour break would then be followed by another transect if conditions allowed. All quantitative dives were completed in either full daylight or nighttime to control for the possible effects of diurnal animal behavior during dusk or twilight.

Video analysis: Two pairs of scaling lasers mounted near the camera assisted in estimating transect width and organism size. The video signal, along with time and date encoding, was recorded on miniDV digital video tapes. Comments were recorded of habitats, organism identification, and other observations in real time in a computer log. Time and geographic position of the submersible were recorded approximately every 2-3 seconds. Still frames from the live video feed provided high-quality images, which were used for organism identification. Voucher specimens of invertebrates were also collected and curated by staff at the Natural History Museum of Los Angeles County.

After completion of dives, the videotape records of the transects were reviewed multiple times with the help of a data recorder. We categorized the substrates within each transect using six standardized codes: rock ridge (R, vertical relief), boulder (B, > 25.5cm diameter), cobble (C, > 6.5cm and < 25.5cm), pebble (P, < 6.5 cm), sand (S) and mud (M) (Stein et al., 1992). Habitat was recorded using two codes, the first indicating primary cover ($\geq 50\%$) and the next indicating secondary cover (20-50%). For example, a boulder-cobble (BC) bottom type consisted of at least 50% cover of boulders and at least 20% cover of cobbles. If a single substrate covered more than 80% of the seafloor, the same letter was used twice, such as a pure mud bottom (MM). Together, the two codes indicated a section of uniform substrate defined as a habitat "patch."

Each transect consisted of many habitat patches and habitat types, depending on the variability of substrate. The 37 different habitat combinations observed were simplified for easier comparison into the ten most common and descriptive patch types based on a previous cluster analysis by Stein et al. (1992). The cluster analysis used data gathered on bottom types and fish abundances.

We determined the length of each habitat patch using the geographic position recorded at the start and end of each patch, or from interpolations made between points when a direct position was unavailable. Using the outside scaling lasers, we estimated the width of each transect by selecting random frames every 10 minutes in each transect and measuring the width of the field of view. Based on these calculations, the average transect width was 1.47 m in 2000 ($n = 102$, $SE = 0.02$) and 2.02 m in 2001 ($n = 128$, $SE = 0.03$). The area of each patch was determined by multiplying the patch length by the average transect width.

Calculation of density: By eye, and with the aid of a tally counter, we counted the number of crinoids as they passed through the plane of the lasers on the videotapes. Density was calculated by dividing the total number of *Florometra* within each habitat patch by the patch area. Crinoid density among years and habitats was analyzed using a two-way analysis of variance (ANOVA). The relationship between crinoid density and depth was analyzed using a Spearman rank correlation analysis.

ArcGIS 8.1 (ESRI) was used to conduct a spatial analysis of *Florometra* density. Geographic points associated with *Florometra* densities were taken from all daytime habitat patches. Using the geostatistical spatial analysis program (ESRI) and an Original Kriging formula (Johnston et al. 2001), we extrapolated the density of *Florometra* across the entire bank. Kriging creates weights from spatially adjacent measured values and predicts continuous values at all unmeasured locations (Johnston et al. 2001). The Kriging procedure is highly flexible; varying the parameters results in different maps. The weights of each point were varied and the number of neighbor points referenced, until the model represented the data with the smallest total standardized mean and with a root mean square standardized closest to 1.0. We decided on a circular model using 12 spatially referenced lags and between 3

- 12 neighbor points. A standardized root mean square of 0.923 supported the ability of the model to accurately predict densities. We used the resulting image to visualize the pattern of abundance across the bank and to generate hypotheses about spatial distribution.

Calculation of size: We estimated the size of crinoids using measurements of arm lengths derived from frames selected from the videotapes in each patch where crinoid arms were seen extended in the same plane of view as the centered lasers. In order to examine several levels of spatial variation I sampled multiple arms on crinoids on all transects in 2000. I used a fully nested model II ANOVA to identify differences among individuals, among aggregations, among patches, among different habitats, and among dives. I used a Spearman rank correlation analysis to examine the relationship between crinoid size, depth and density.

RESULTS

Area and habitat sampled: Transects covering 9.0 ha were completed in 2000; an additional 7.6 ha were surveyed in 2001. While shorter transects with both day and night replicates in 2000 added to the total area covered in the first year, there was fewer unique stations sampled in 2000 than in 2001. Thus, broader coverage of Heceta Bank was achieved in 2001. Comparisons were first made between replicate transects taken during the day and night in 2000 (Table 1). Based on this comparison, further analysis consisted of ten daytime transects replicated in each year, using a total of 337 habitat patches in 2000 and 482 in 2001. These transects occurred on 5 of the 6 previously sampled stations and a sixth station located near station 4. Crinoid density was calculated on the eight other stations and used in spatial analysis and sampled for crinoid arm length (Table 1). However, these data were omitted from inter-annual comparisons due to the lack of replication between years.

Approximately the same area of pure ridge and mud habitats were sampled in both years, while the mixed substrate types had variation in the areas sampled (Table 2). Ridge and cobble-boulder were the most abundant habitats sampled and all stations were composed of multiple habitat types (Figure 4), supporting the method of comparisons between habitat patches, in contrast to between stations, for analysis.

***Florometra* density:** There was a significantly higher density of crinoids at night relative to day (Figure 5, $F = 10.2$; $df = 1, 339$; $p < 0.05$) and among habitats in 2000 ($F = 12.3$; $df = 8, 339$; $p < 0.05$). However, there was no significant habitat by day-night interaction ($F = 1.34$, $df = 8, 339$; $p > 0.05$). Due to this difference in day–night abundance, and the lack of night data in 2001, further analysis was limited to data collected during the day in 2000 and 2001.

The mean density of crinoids over both years was 35,480 ha⁻¹ (SE = 2346). However, a two-way ANOVA showed a significantly higher density of crinoids in 2000 than in 2001 ($F = 4.29$; $df = 1, 799$; $p < 0.05$) and a significant difference across habitats ($F = 12.87$; $df = 9, 799$; $p < 0.05$), but no significant interaction ($F = 0.79$; $df = 9, 799$; $p > 0.05$) (Figure 6).

A maximum of 412,371 crinoids per ha⁻¹ occurred on ridge habitats while few were generally found on mud habitats (Figure 6). Crinoids were more abundant on hard substrates such as those found in ridge, boulder, and cobble habitats, but the occurrence of these substrates did not ultimately predict the presence of crinoids as rocky substrate without crinoids were often seen. There was a general decrease in crinoid density as habitat type changed from rocky substrates to mud covered substrates in deeper water (Figure 6). There were very few crinoids found on pure mud (mean = 200 ha).

Density was significantly, negatively correlated with depth ($r = -0.165$, $p < 0.05$). *Florometra* densities were highest between 74 m and 130 m with a peak at 111 m and decreased into deeper areas of the bank.

Spatial analysis indicated that the southern, shallow bank areas (i.e. Station 3) had the highest concentration of crinoids, with abundance decreasing as depth increased along with the incidence of mud habitats (Figure 7). There was a gradient of distribution on an East-West axis with higher abundance toward the center of the bank top and also toward the Southern bank top. No crinoids were found on the shallow north bank and almost none on the shelf slopes. However, although areas around Station 3 on the south bank were quite shallow, crinoids were found in high abundance.

***Florometra* size:** Crinoid size displayed a positively skewed distribution, indicating a higher abundance of small relative to large individuals (Figure 8). The smallest arm length measured 1.6 cm while the largest measured 30.0 cm. Overall mean crinoid arm length was 11.3 cm. Not all factors in the Model II ANOVA were significant (Table 3). The greatest spatial variation was found among individuals within an aggregation, then among aggregations and among habitats. There was no significant variation among habitat patches or among dives. Crinoid size increased significantly with depth ($r = 0.28$, $p < 0.05$); however, no correlation was found between crinoid size and density ($r = -0.04$, $p > 0.05$).

DISCUSSION

Florometra was distributed throughout Heceta Bank primarily on ridge and boulder habitats between 70 m and 340 m. Maximum density was reached on the south bank top and decreased into deep, muddier habitats (Figure 7). The

shallow areas of the north bank had no crinoids and the saddle between the two tops exhibited an average density. The daytime crinoid abundance underestimated the true crinoid density found on Heceta Bank as demonstrated by a 34% increase in abundance at night. A 12% decrease in abundance between 2000 and 2001 was also observed. The pattern of abundance for each habitat did not vary among years.

Possible factors important to *Florometra* distribution: Substrates with high rugosity, determined from submersible observations and the bathymetric map, had a higher density of crinoids than other areas. *Florometra* populations do not seem to be limited by depth, but by lack of suitable habitat and/or a suboptimal physical environment. Although there was ample rocky substrate on the shallow north bank top, crinoids were not present. Instead, basketstars (*Gorgonocephalus eucnemis*), another large filter-feeder, were common (personal observations). Additionally, both basketstars and crinoids were common on the mid-bank areas. The bareness of the ridge on the north bank top may be due to large physical disturbances or strong currents and may represent a suboptimal physical environment for crinoid aggregation. The abundance of crinoids on the shallow areas of the south bank may be due to the absence of such physical forces.

Hydrodynamics near the seafloor may influence aggregations due to the sensitivity of crinoids to changing current and available habitat (Day et al. 1971, Meyer 1994). Optimal conditions are different for each benthic species, making the presence of specific organisms the best indicators of the local conditions (Day et al. 1971, Messing 1985). Meyer (1973) correlated Caribbean crinoid distribution with optimum exposure to water movement. In subtidal habitats, crinoids may avoid wave stress because they can retreat into crevices under extreme conditions (Meyer 1985). *Florometra* may be absent from shallow areas of the north bank because of the lack of crevices for shelter (there are no boulders or cobbles present). Byrne and Fontaine (1981) stated that *Florometra* colonized habitats where strong current was absent. However, during this investigation *Florometra* was observed in areas of high current at deeper depths (i.e. Station 10). Yet turbulence created by the submersible severely affected *Florometra* by blowing them off the substrate. Larger populations of another crinoid, *Diplocrinus wyvillethomsoni*, were also correlated with moderate current regimes. They did not occur where ripple marks were visible in the substrate, making its' distribution dependent on substrate as well as current velocity (Conan et al. 1981). Further, all deep-water crinoids from the tropical Western Atlantic are thought to be absent in habitats with strong currents (Messing 1985).

Florometra observed *in situ* position themselves as high as possible on the substrate. We observed this behavior on all substrate types and at all depths. Shaw and Fontaine (1990) also observed this in 17-34 m of water and when *Florometra* was held in an aquarium. This behavior is thought to keep individuals away from soft sediment and in better position for feeding (Shaw and Fontaine 1990). In contrast, some areas which were covered with thick sediment, such as the deep, south shelf slope, contained *Florometra* at medium densities. It is possible that the south

shelf slope receives more nutrients than other mud covered areas, which could explain the moderate density of crinoids. A consistent current supplying additional nutrients may offset the additional influx of sediments to the benthic community. The correlation analyses supports this hypothesis because although density decreased with depth, the average crinoid size increased.

The absence of a correlation between crinoid size and density does not support a hypothesis of resource limitation in dense aggregations. Even in very dense aggregations, there was no measurable decrease in crinoid size and a mixture of crinoid sizes persisted in all environments. Although crinoids are an active part of the filtering community, their dense aggregations are not believed to limit the amount of seston available in the water column (Gill and Coma 1998). Instead, the baffle effect caused by filtering arms increases the residence time of particles in their direct vicinity enhancing feeding efficiency (Meyer 1973, Gill and Coma 1998). Smaller crustaceans and detritivores can benefit from the presence of a large aggregation of feeders by exploiting the additional nutrients. In the presence of *Florometra*, more species were present including filter-feeders, asteroids, octocorallians, anemones and ophiuroids. Similarly, Hixon et al. (1991) observed several other species in association with *Florometra*. *Florometra* may be an important component of this community, providing shelter, increasing the supply of nutrients and adding three-dimensional habitat.

Possible factors important to *Florometra* temporal variation: The rarity of small individuals may indicate a lack of recruitment, high juvenile mortality, or an inability to sample or observe juveniles within dense adult aggregations or below a certain threshold. Mladenov (1981) stated that *Florometra* exhibits a continuous breeding pattern and an exponential growth rate of juveniles and young adults. The positively skewed population may represent this fast development and continual recruitment, limiting the abundance of individuals below approximately 8 cm in length.

The significantly higher densities of *Florometra* at night has not been previously described. Disturbance from fishes preying on symbionts or the mucous strands of crinoids in the Marshall Islands promoted diurnal migration where the abundance of many nocturnal crinoid populations in shallow-water often exceeded that of day-active populations (Zmarzly 1985). While some crinoid species observed in shallow-water in the West Pacific displayed only nocturnal emergence, others showed no change in behavior in response to diurnal cycles (Zmarzly 1985). The large difference in density between day and night (34%) suggests there is a behavioral characteristic altering short-term *Florometra* abundance but these observations do not provide enough evidence to consider *Florometra* a nocturnal species.

Movement of individuals may occur as a result of seasonal or daily migrations, as is displayed by many crinoids species (La Touche 1978, Meyer 1985). The crinoid *Antedon bifida*, considered to be an Atlantic equivalent of *Florometra* (Byrne and Fontaine 1981), is also thought to be nomadic, appearing to migrate in particular regions or between seasons (La Touche 1978).

Implications for crinoid - fish associations: Hixon et al. (1991) suggested that the presence of juvenile fish in ridge and boulder habitats on Heceta Bank was attributable to the abundance of vertical relief, shelter, and food. Sponges, octocorallians, sea-pens and bryozoans have been shown to provide vertical structure in the deep, northern and southern benthic community of the oceans (Dayton et al. 1974, Starmans et al. 1999, Beaulieu 2001, Brodeur 2001). We think that crinoids may play a similar role on Heceta Bank. The high density of crinoids observed (mean = 18,919 ha) clearly creates large areas of living refuge and shelter that are important to the hard substrate benthic communities (Messing 1985).

Juvenile fish were often seen among the arms of crinoids, especially in areas of high crinoid density (Figure 2). Crinoids are often associated with symbionts, which fish and crustaceans may use as a food source (Meyer 1985, Young and Emson 1993, VandenSpiegel et al. 1998) and many organisms were seen associated with the habitat and at the bases of *Florometra* aggregations (personal observations). However, no associated organisms were observed living within *Florometra* in this study. Predation on *Florometra* by rockfish has not been confirmed by any investigators on the west coast of North America (W. Wakefield; M. Yoklavich; G. Caillet; V. O'Connell, personal communications) however predation on symbionts of *Florometra* cannot be discounted. *Florometra* populations in subtidal water off Vancouver Island had a high incidence of unexplained autotomy (Mladenov 1983), but the loss of arms is thought to be caused by fish accidentally knocking them off while preying on associated organisms rather than the actual crinoid (Young and Emson 1993).

Conclusion: *Florometra* is an abundant and conspicuous filter-feeder on Heceta Bank providing a living, three-dimensional habitat. *Florometra* aggregations may be a consistent indicator of local hydrodynamics because they occur over broad depth ranges, habitat types, and time. These aggregations, as visualized in the *Florometra* spatial distribution map, could be integrated into habitat-based assessments.

Movement of invertebrates on continental shelves has not received much attention and this may be due to difficulties in observing such behaviors. The capability of making day and night observations as demonstrated in this study, will increase as remotely operated vehicles become more widely used for scientific research. Because geographical positioning is also quite accurate, equipment, such as an underwater camera, can be deployed and retrieved at a later time from the same location with confidence. These capabilities will allow investigation of the daily and seasonal behavior of more subtidal organisms.

Invertebrate data such as those used in this research are easily collected from videotapes made for other purposes (e.g. fish transects). If transects are planned with a clear quantitative goal, biotic and abiotic factors of habitat can be associated with the principal observations. There are many methods designed to complete these analyses including Hixon et al. (1991), Greene et al. (1999) and Bax et al. (1999).

As the importance of associating particular habitats to groundfish populations is realized, a universal method for defining habitat will become necessary. This research has provided data regarding habitat type as defined by the physical and biotic distributions and interactions of *Florometra*. The integration of multiple aspects of the *Florometra* community provides a definition of habitat type that may be useful for future assessment and management of important fish species such as juvenile rockfish. Progress is being made in quantifying habitat characteristics (Fogarty 1999) especially in regard to aggregating invertebrate populations. As we come to understand the importance of these associations, a biotic component of habitat will be more easily integrated.

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Table 1. Summary of quantitative ROPOS transects completed on Heceta Bank, OR, in 2000 and 2001. The time of transects (PST) is presented along with total area covered (ha) and mean crinoid density (no ha-1).

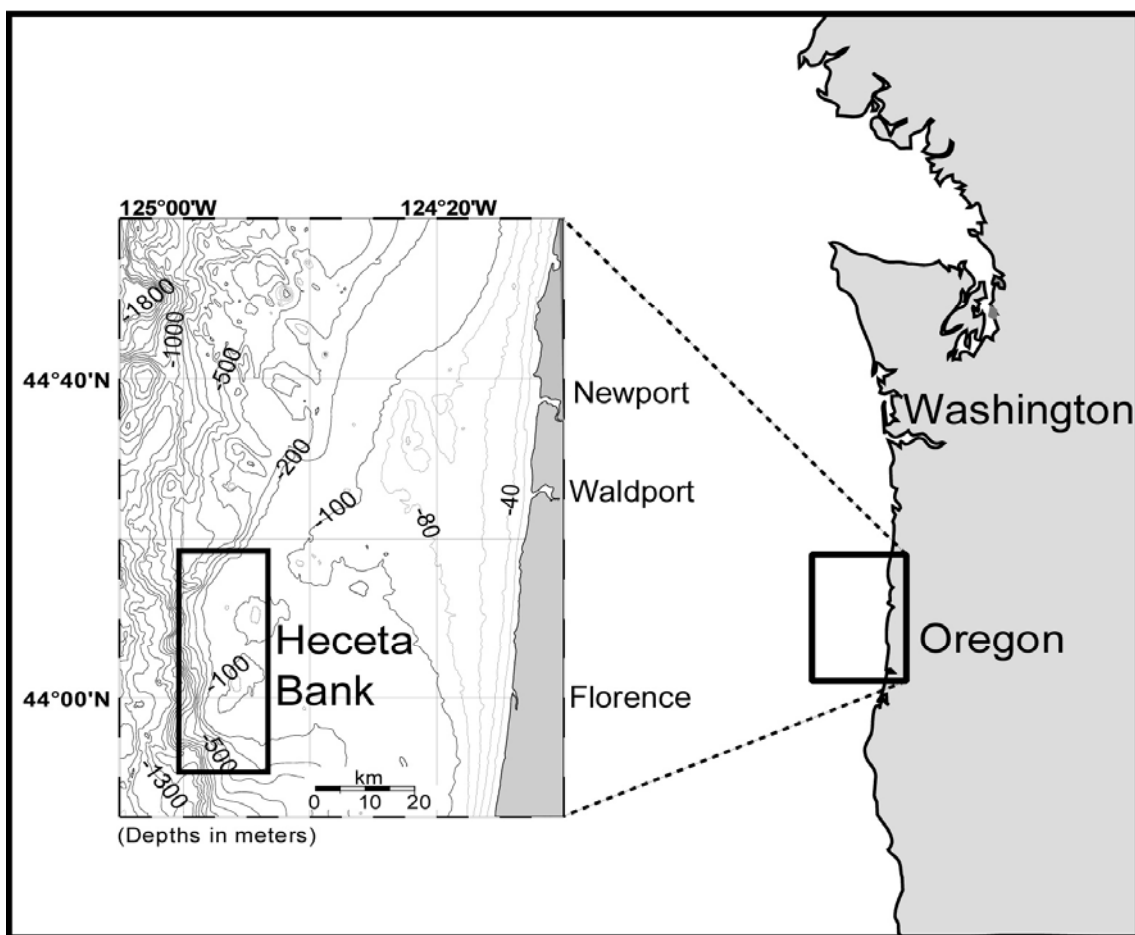
Year	Station	Dive	No. of Transects	Date	Time of Day	Time Range	Depth (m)	Area (ha)	Mean Density of Crinoids (no ha-1)
2000	1	529	2	21/06/00	Day	1346-1623	69-89	1.04	0
	2	531	2	21/06/00	Day	1306-1601	92-174	0.69	0
			2	21/06/00	Night	1650-1943	92-174	0.68	0
	3	532	2	22/06/00	Day	1600-1757	72-126	0.62	42,417
			2	23/06/00	Night	0135-0332	71-123	0.68	63,363
	4	527	1	19/06/00	Night	0245-0346	87-147	0.72	45,633
			4	19/06/00	Day	1432-1648	114-200	0.93	21,469
	6	534	2	23/06/00	Day	1243-1845	136-341	0.32	9,987
			1	24/06/00	Night	0023-0304	138-336	0.39	10,725
	8	536	2	25/06/00	Night	2051-0203	170-332	0.52	0
2001	9	537	1	26/06/00	Day	1622-1829	101-126	0.38	22,039
			2	26/06/00	Night	1717-0234	100-126	0.40	13,385
	10	539	4	26/06/00	Day	1123-1359	112-315	1.62	35,287
	1	608	2	07/07/01	Day	0738-1305	69-92	1.14	4
	2	606	2	06/07/01	Day	0634-1018	149-175	0.88	0
	3	605	2	05/07/01	Day	1412-1647	71-128	0.98	32,061
	4	610	2	08/07/01	Day	1021-1320	101-130	0.82	25,915
	6	604	2	04/07/01	Day	1411-1722	135-342	0.48	939
	9	610	1	08/07/01	Day	1021-1320	101-130	0.37	25,915
	12	611	1	09/07/01	Day	0802-0821	159-196	0.11	0
	13	617	1	11/07/01	Day	1112-1648	117-163	1.03	42,423
	16	613	1	09/07/01	Day	1312-1655	75-125	0.79	13,543
	17	615	1	10/07/01	Day	1139-1646	118-147	0.76	0

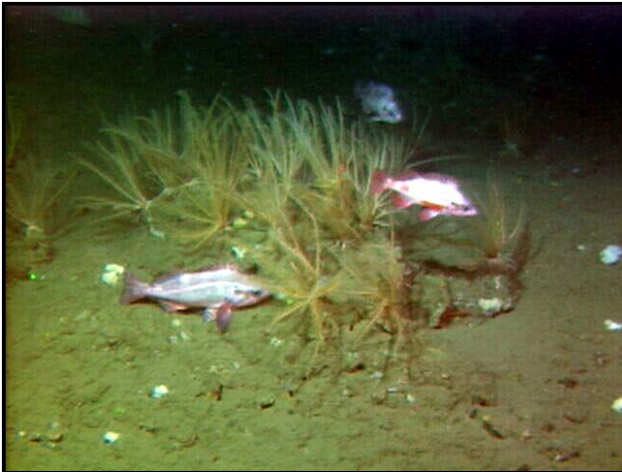
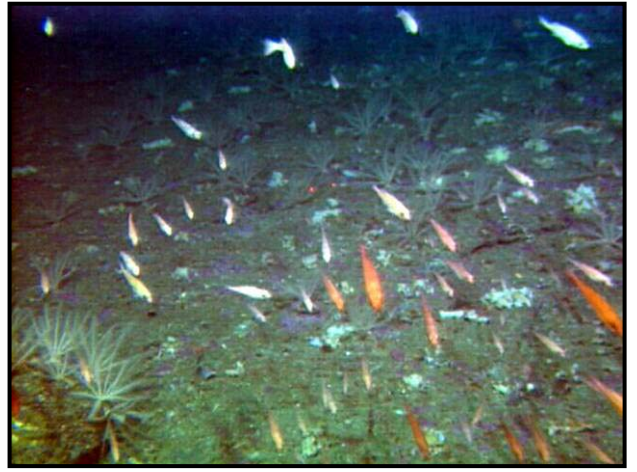
Table 2. Summary of area of bottom types sampled in the daytime in 2000 and 2001. N represents sample size of patches. (RR = ridge, BB = boulder, BC = boulder-cobble, CB = cobble-boulder, CC = cobble, CM = cobble-mud, MB = mud-boulder, MC = mud-cobble, MP = mud-pebble, MM = mud.)

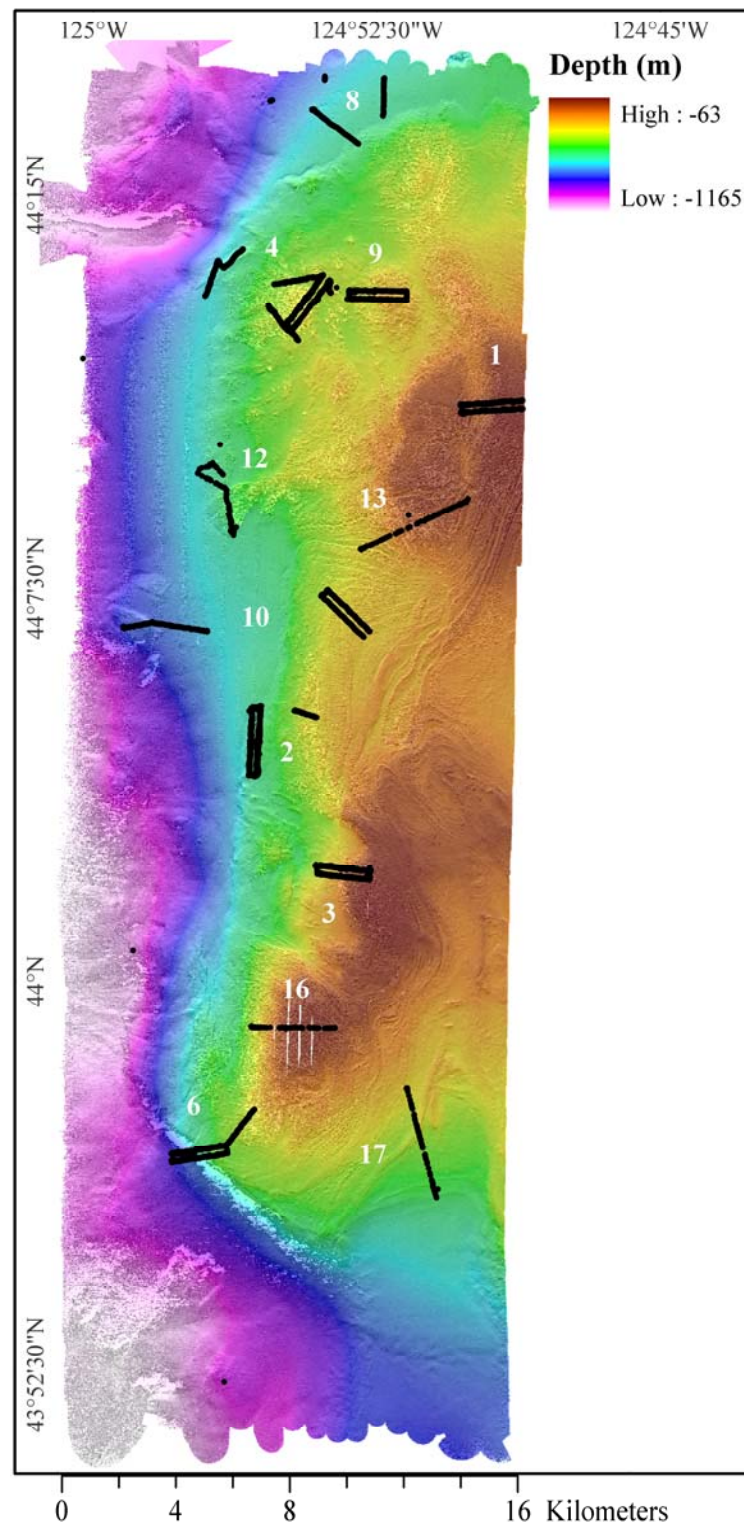
Bottom Type	<u>2000</u>		<u>2001</u>	
	Area (ha)	N	Area (ha)	N
RR	1.30	115	1.78	166
BB	0.09	21	0.55	58
BC	0.31	13	0.58	37
CB	0.86	52	0.44	45
CC	0.31	37	0.24	29
CM	0.34	33	0.33	53
MB	0.06	8	0.26	29
MC	0.19	23	0.09	9
MP	0.09	17	0.17	32
MM	0.18	18	0.23	24

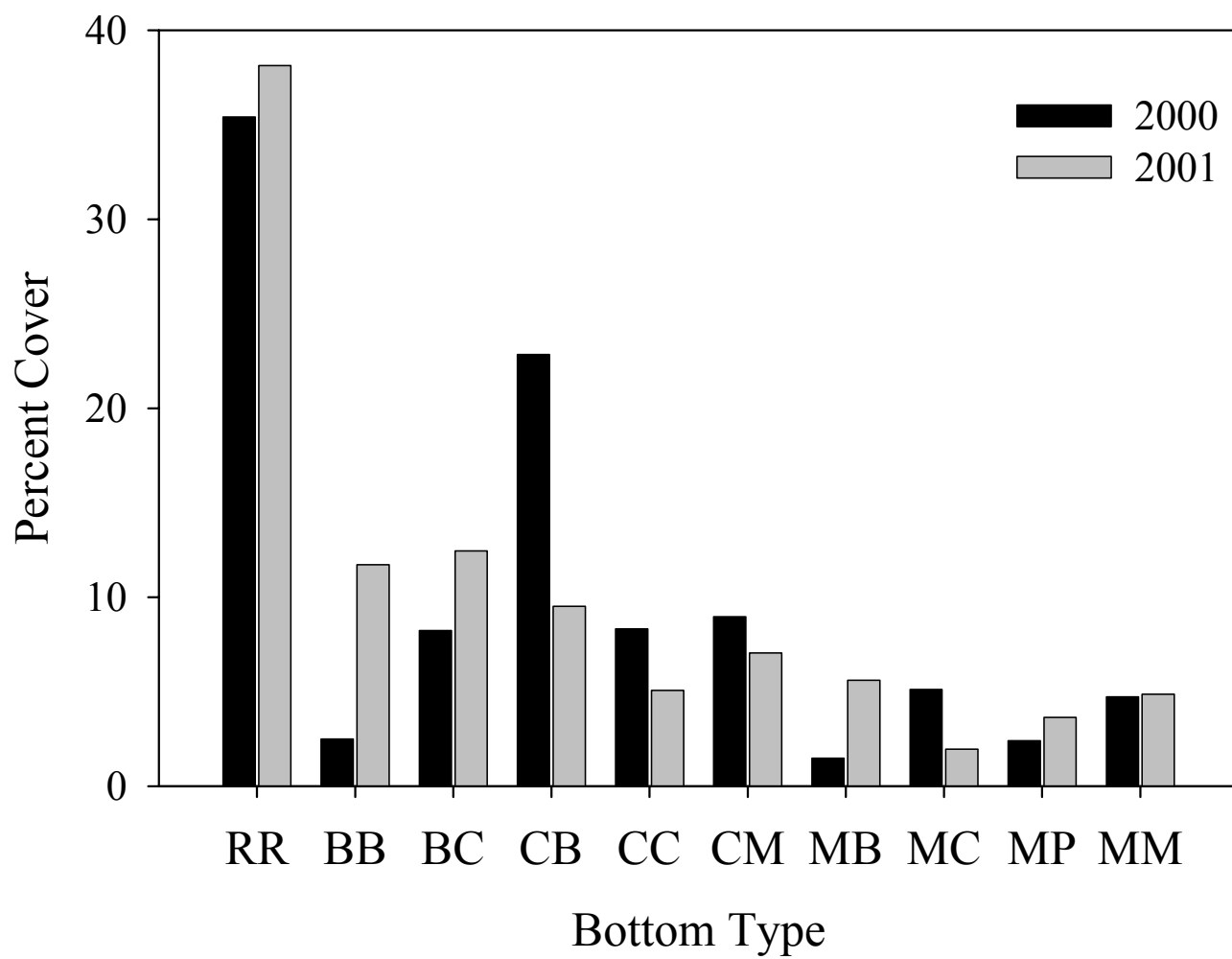
Table 3. Model II ANOVA assessing the size variation of *Florometra serratissima* at multiple spatial scales. An asterisk represents an F-value where $p < 0.01$.

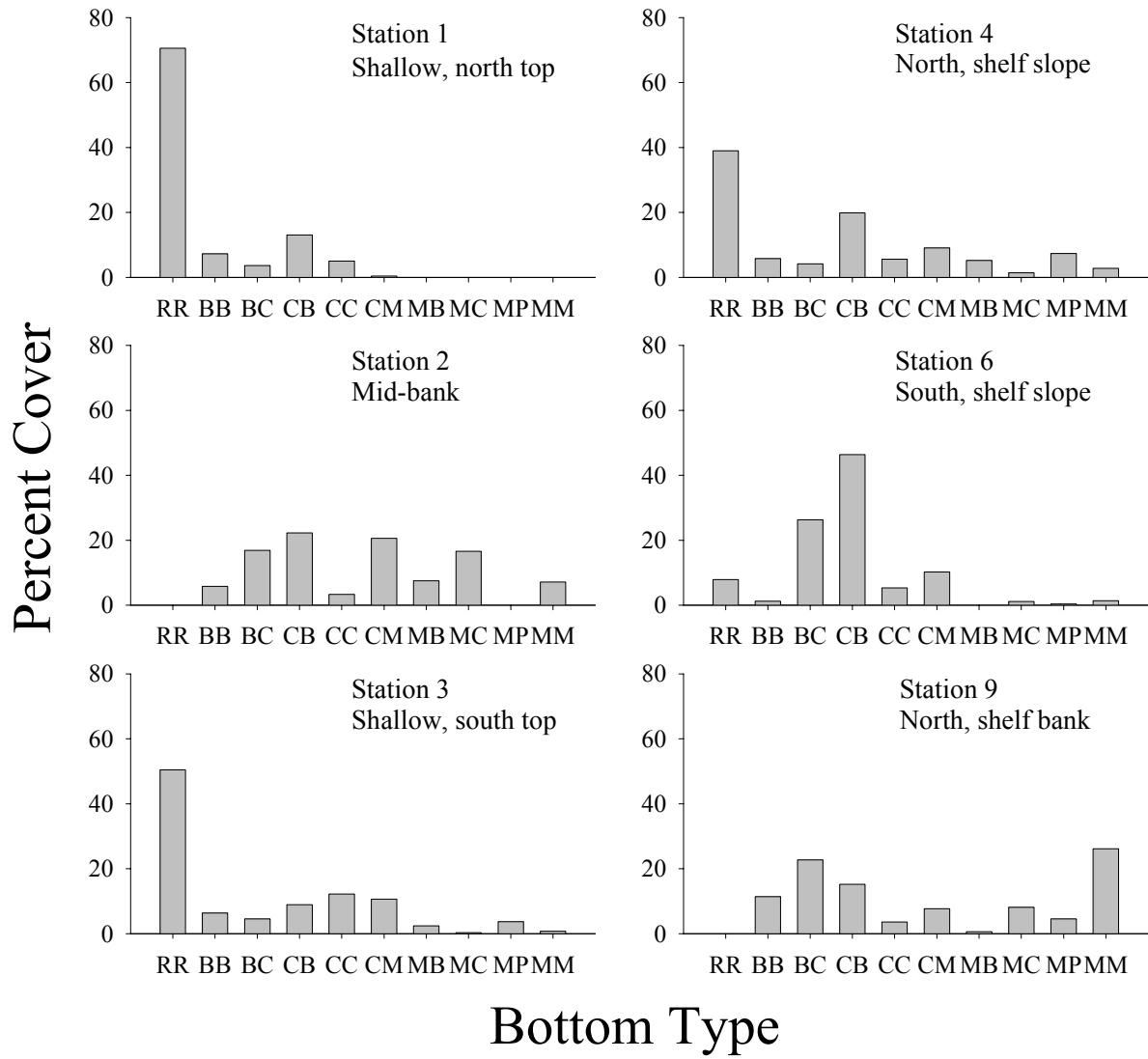
Source	df	MS	Percent Variation	F-value
Among Dives	6	109.5	0.27 %	1.6
Among Habitats	25	68.0	9.58 %	2.4*
Among Patches	54	28.9	0.01 %	1.0
Among Aggregations	115	28.6	16.5 %	1.7*
Among Individuals	395	17.0	58.3 %	10*
Error	854	1.7	15.3 %	

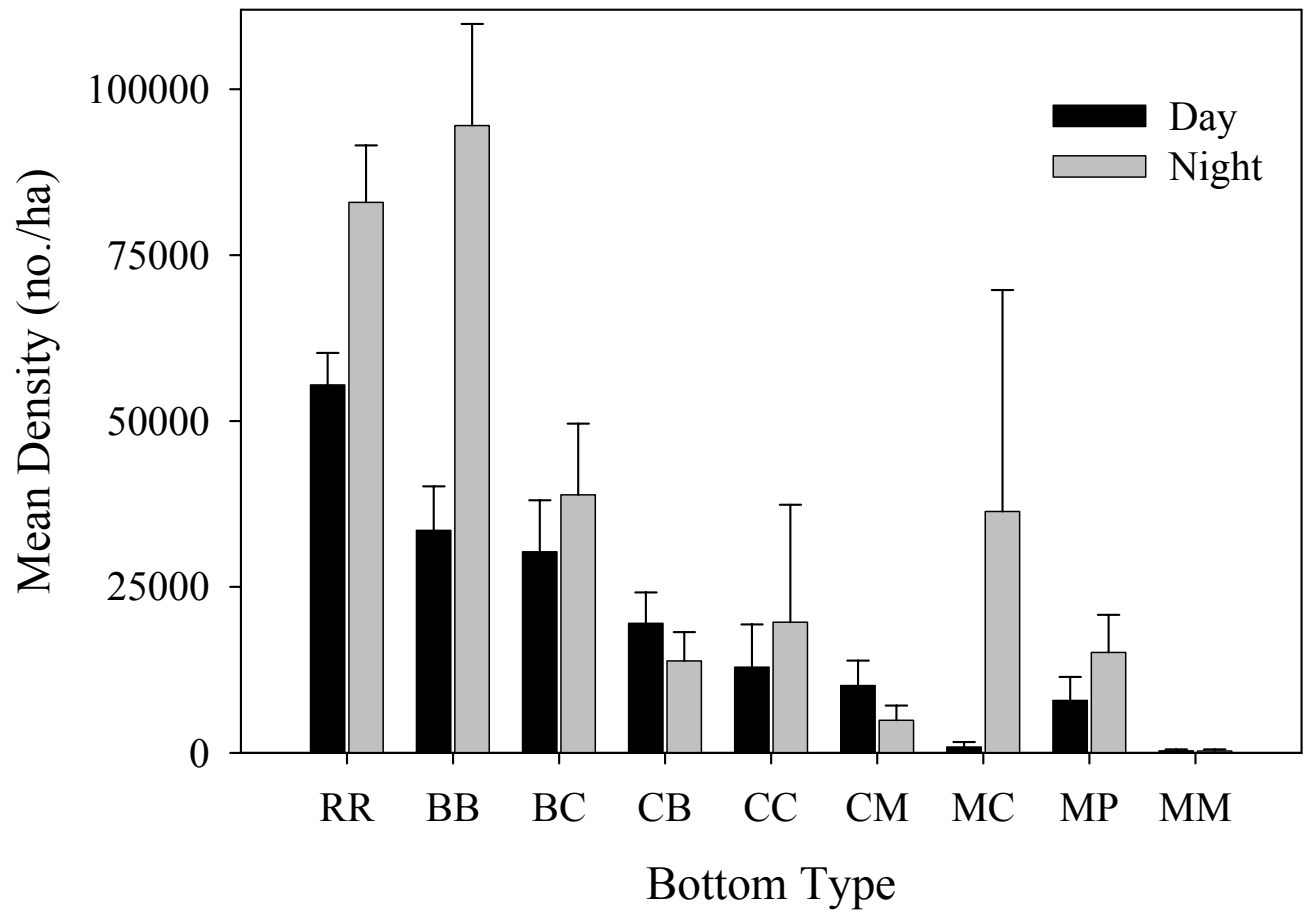


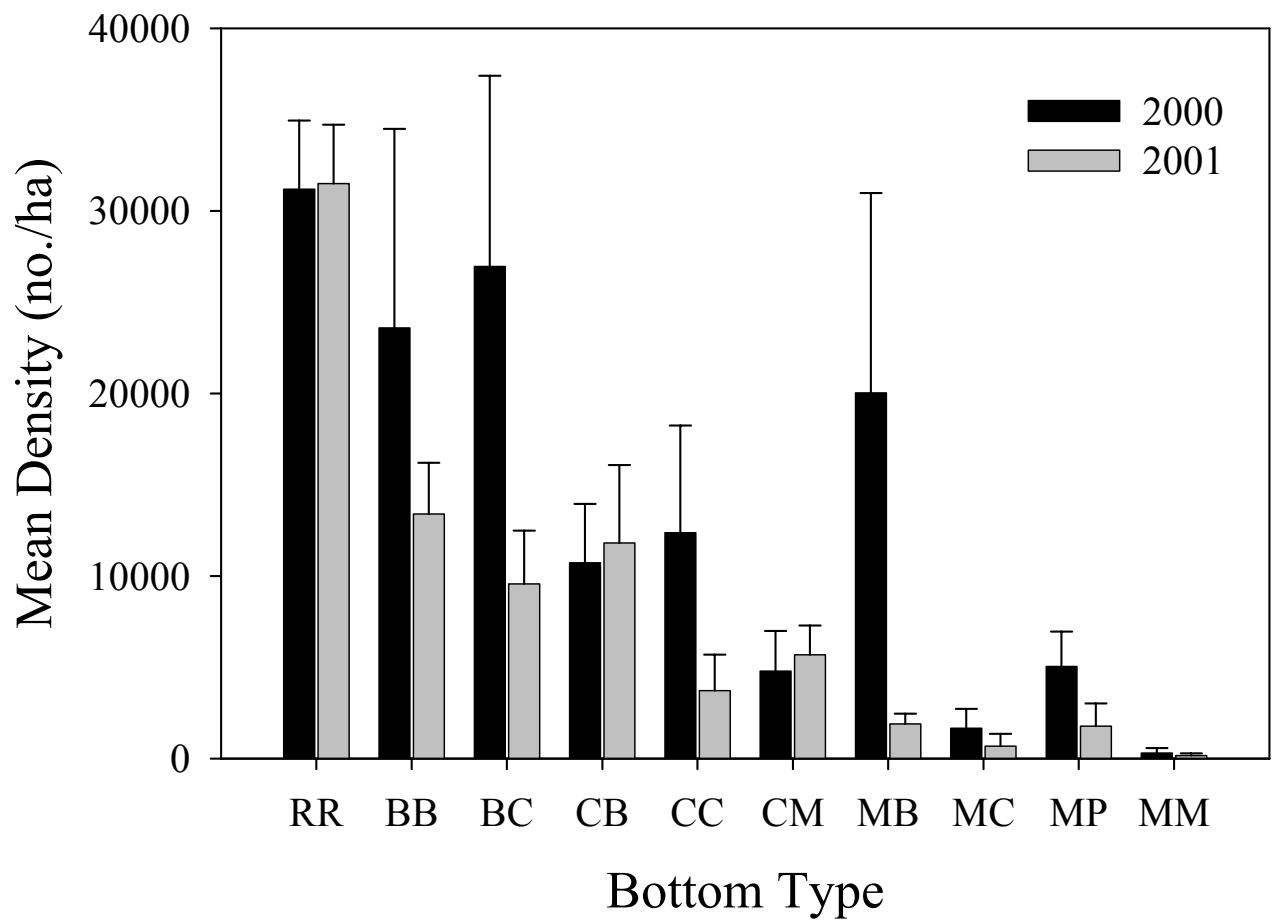


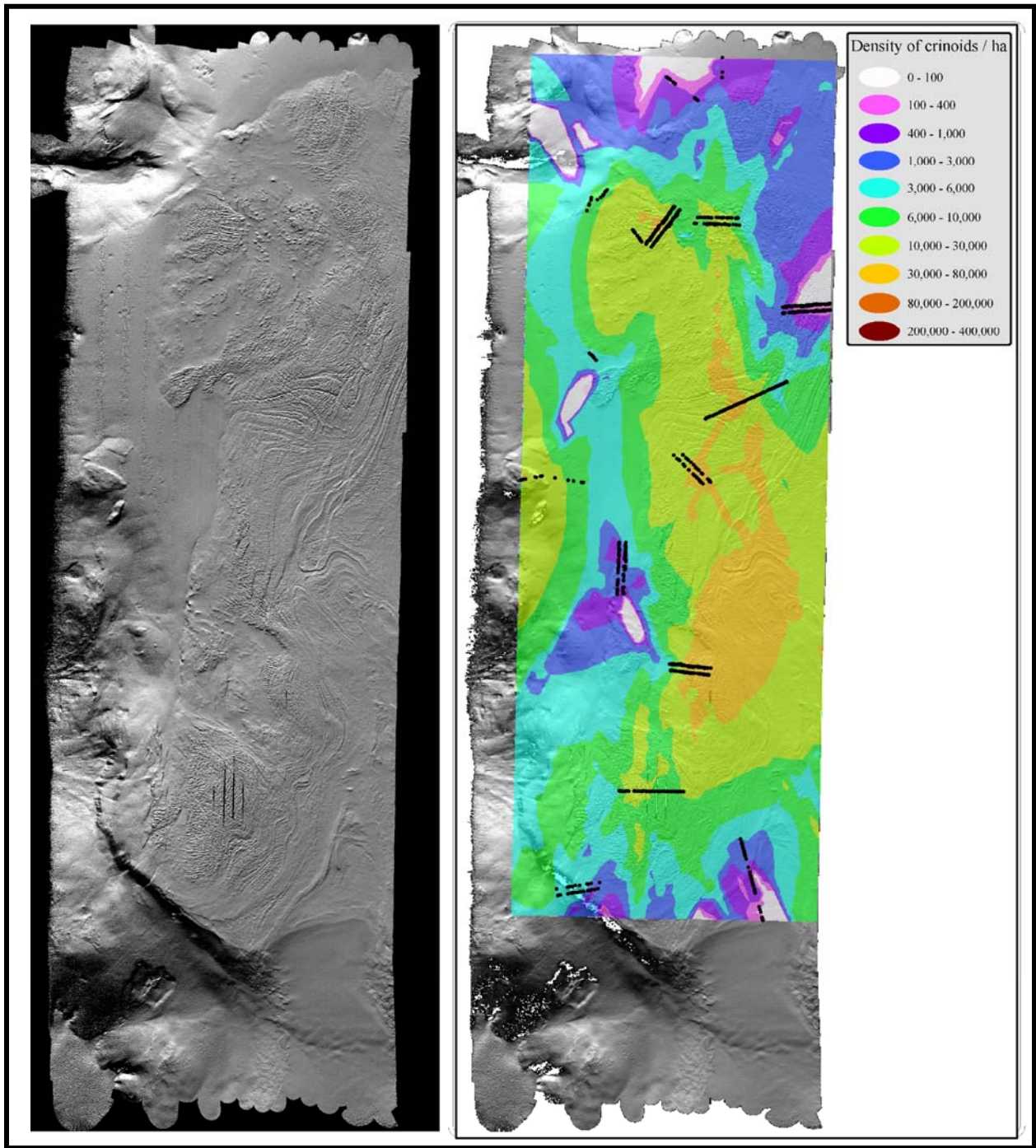












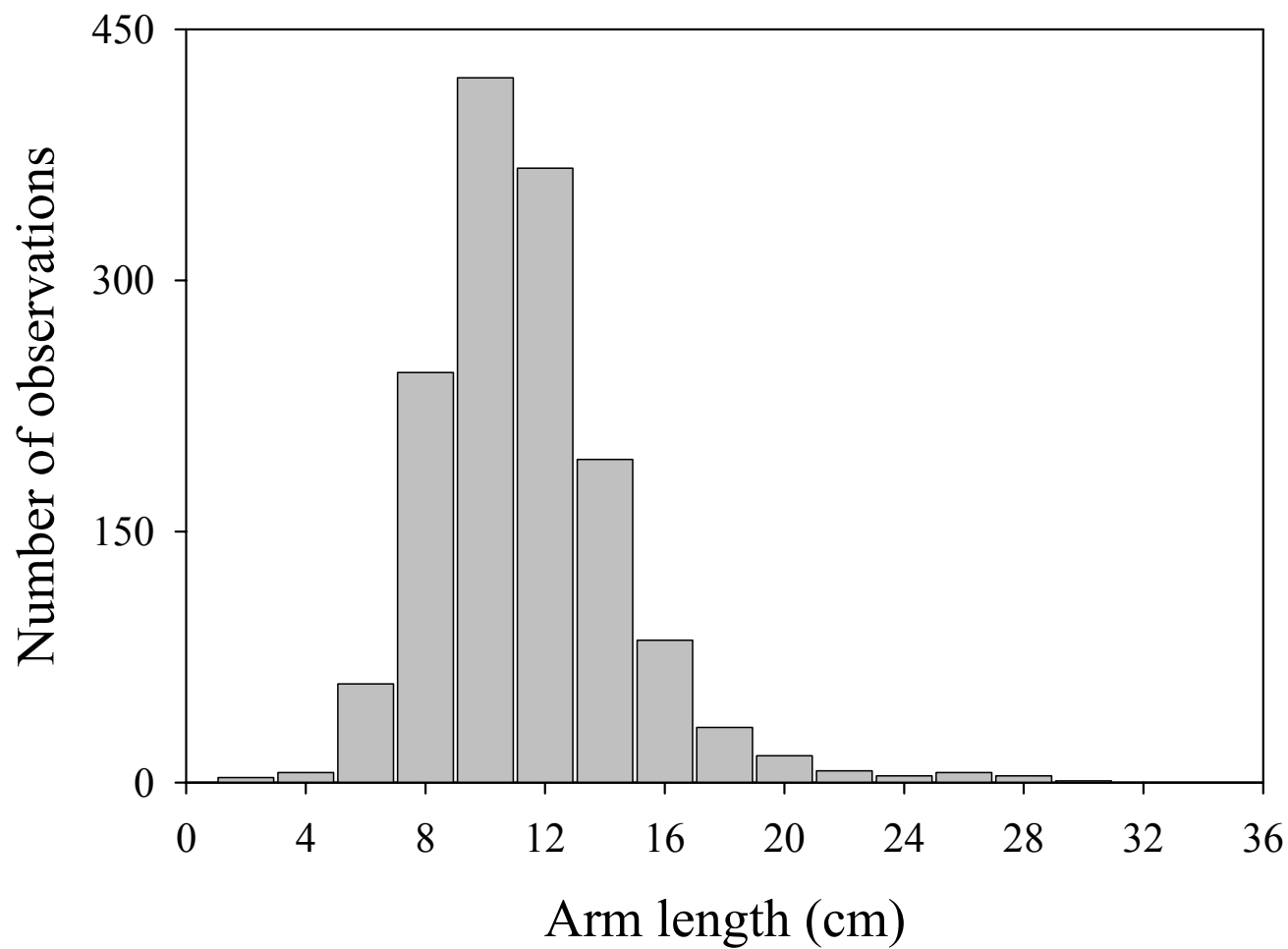


Figure 9. Length distribution of crinoid arms sampled on Heceta Bank, OR, in 2000 (n = 1450).