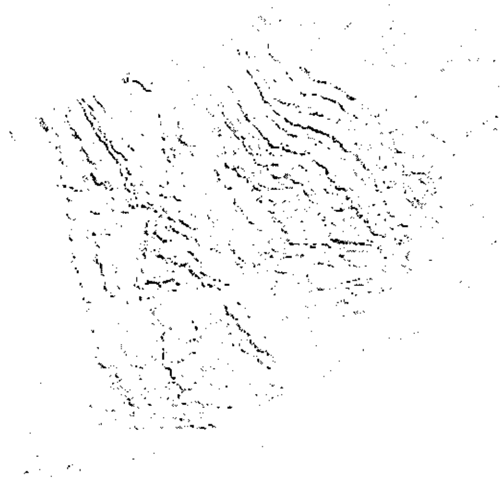
How anchoring locations can be changed to minimize damage to sensitive habitats near Monterey Harbor



A Capstone Project

Presented to the Faculty of Earth Systems Science and Policy

in the

Center for Science, Technology and Information Resources

at

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in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science

by

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Cover Letter

Anchor damage is both a global issue and a local issue. Countries such as Australia, Belize, Brazil and the United States are beginning to recognize damage done to sensitive marine habitats as a result of dropping anchors. While action is being taken towards reducing anchor damage, the idea has not been fully recognized in Monterey, California. This Capstone project involved determining the most ideal locations for vessels to anchor near Monterey Harbor. These locations are based on a current set of criteria which vessels use when anchoring. I formulated my own additional criterion with the intention of protecting the high relief ledges of the shalebeds, a sensitive marine habitat off Del Monte Beach, from anchor damage. This project is significant because it addresses an important global issue as it relates to Monterey.

This Capstone project focused on several interactions involving socioeconomic, political and ecological components. As I researched the biotic communities within the shalebeds, I gained an appreciation for their diversity and therefore want to protect this underwater environment from anchor damage. Accordingly, I used this research to devise appropriate criteria for anchoring near Monterey Harbor. I recommended alternative locations for anchoring sites that are just as safe for vessels. Thus, vessels would not be inconvenienced and the shalebed habitats would be protected from anchor damage. I feel that I have increased public awareness and support for this issue and therefore for the protection of the shalebed habitats.

Several organizations and agencies have shared relevant and useful information in regards to my project. The United States Coast Guard, the California Department of Fish and Game and the Monterey Harbor Office have been of great assistance. I have also been given anchoring information from the California Maritime Academy. I presented this information to the Monterey Bay National Marine Sanctuary as the Sanctuary's Research Coordinator/Senior Scientist expressed an interest in the project. In addition, the Monterey Harbor Office, the Monterey Public Library and the United States Coast Guard's Law Enforcement Department all requested a copy of my Capstone. The Coast Guard's Law Enforcement Department works in collaboration with the Monterey Bay National Marine Sanctuary and the National Oceanic and Atmospheric Administration. I have also collaborated with the Institute of Earth Systems Science and Policy's Seafloor Mapping Lab.

This Capstone project is geared towards educational institutions, maritime organizations and agencies involved in marine policy and marine environments. It is written for conservationists, environmentalists and policy makers interested in learning about the shalebed's physical structure and biotic communities. I hope that agencies and organizations will carefully consider my Capstone when reviewing current marine issues in Monterey.

I believe that the benefits of anchoring in less sensitive areas outweigh anchoring in the shalebeds where marine life could potentially be destroyed. In the past, I have been challenged to consider my own values towards natural environments. Prior to this Capstone, I was unaware of the sensitive shalebed habitat. Since there are no regulations on anchoring, I thought that vessels had the right to anchor at any location. The shalebed habitat has become an especially important ecosystem to me. Through studying and watching underwater videos of the area, I have gained an appreciation for the diversity and structure of this habitat.

In this Capstone, I am addressing the following two Areas of Depth: MLO #3: Applied Scientific Knowledge Competency and MLO #5: Data Acquisition Analysis and Display Competency. For MLO #3, I developed hypotheses and questions based on current anchor locations near Monterey Harbor and criteria vessels use for anchoring. I used this scientific knowledge to propose alternative anchoring locations that will minimize damage to the Monterey Bay shalebeds. For MLO #5, I created maps displaying appropriate anchoring locations and areas to be avoided by vessel's anchors. By using technology such as ArcView and TNT Mips, I was able to propose alternative anchoring locations.

While records have been kept of the occurrences of anchorages near Monterey Harbor, I was concerned that there are no regulations on anchoring locations. As an Earth Systems Science and Policy major, I feel that the Monterey Bay should have more strict regulations on anchoring as it is a National Marine Sanctuary. Even though anchor damage occurs beneath the ocean's surface, I feel that it should be recognized and studied further in order to fully understand these impacts.

Through this project, I have gained skills in marine technology and knowledge of scientific approaches as applied to real world problems and issues. I have learned about the physical structures and biotic communities of the shalebed habitat. I hope to influence regulations on anchoring locations near Monterey Harbor based on my suggested anchoring criterion as it relates to the shalebed habitat.

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Abstract

Anchor damage is a global as well as a local issue. Countries around the world are beginning to recognize damage done to sensitive marine habitats as a result of dropping anchors. Damage may also be occurring to the shalebeds off Del Monte Beach in Monterey, California. As vessels drop anchor near Monterey Harbor, stress is added to the shalebeds which may result in high relief ledges becoming rubble piles. The shalebeds are underwater structures which offer shelter to a wide range of marine species. My general approach was to find out if vessels are anchoring on the shalebeds and if so, propose alternative locations for anchoring. I used Geographic Information Systems (GIS) and Acoustic Remote Sensing Data to distinguish between high relief areas most susceptible to anchor damage and low relief and sandy areas that still meet the anchoring requirements of vessels. I contacted various organizations that shared relevant information about current anchoring criteria and sites near Monterey Harbor. Based on this information, I used ArcView and TNT Mips to create maps displaying alternative anchoring sites. I recommended alternative anchoring locations in sandy areas adjacent to the shalebed's high and middle relief structures which minimize damage to the shalebed habitat while meeting anchoring criteria for vessels.

Introduction

Anchor damage to sensitive habitats is a global issue. Several countries are finding solutions to the issue of vessels dropping anchor on marine habitats. Evidence of anchor damage has been found in a variety of locations including Anguilla, the Bahamas, Belize, Bermuda, Bonaire, the British and Virgin Islands, Honduras, the Philippines and Trinidad. Countries are beginning to take action towards protecting the marine environment from anchor damage. This includes conservation through the installation of well-designed moorings in sensitive areas (Harris, 2000) and increasing the number of cruise ship moorings (Pattullo 1998). According to Stephen H. Smith, a marine ecologist at Environmental Technologies International, the most effective solution to reducing damage caused by anchors is to provide permanent moorings and to require that boats do not drop anchor (Allen 1992).

Anchor damage to coral formations in Florida has been studied by the Florida Keys National Marine Sanctuary. It was determined that "the larger the vessel, the greater the risk of damage to coral if an anchor is used (FKNMS 1999). Similarly, in Grand Cayman, anchor damage to coral occurred where the anchor chain swayed with the ship and 'crushed snapped, or twisted any coral in its path" (Allen 1992).

Anchor damage may be occurring in the shalebeds off Del Monte Beach near Monterey Harbor in Monterey California. An anchor falling atop a shalebed may cause both physical and biotic damage. Therefore, action needs to be taken to reduce the amount of damage to the shalebeds.

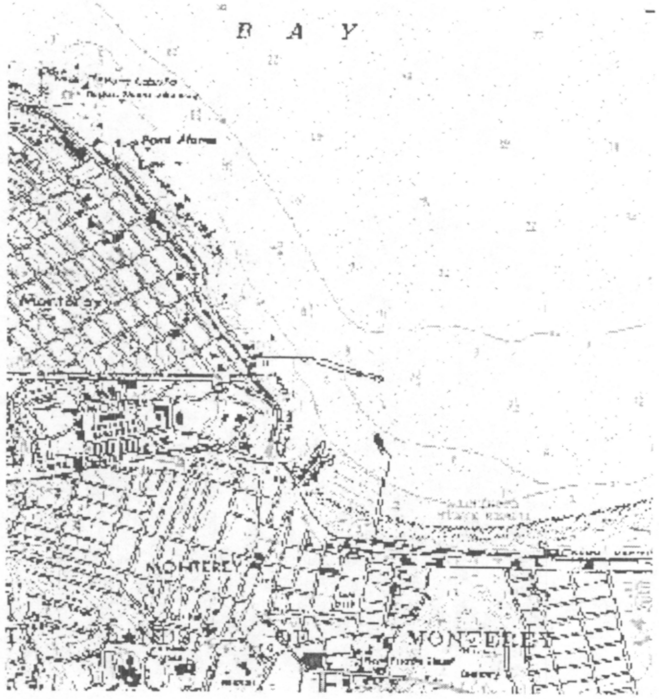


Figure 1. Quad map of Monterey Harbor displaying Coast Guard Wharf and Wharf No. 2.

Monterey Bay Shalebeds

The shalebeds off Del Monte Beach are underwater structures which occur in shallow water of 6 m – 8 m of water and continue out to 50 m deep or more (Iampietro 2000). They are a macrohabitat which have features with dimensions from kilometers to tens of kilometers and larger (Greene 1999). There are various relief structures found in this environment which include areas of high, middle and low relief and sandy areas.

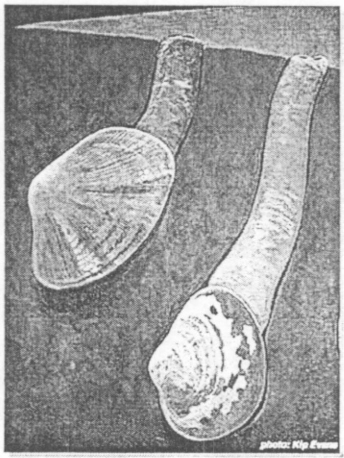
Physical Habitat

The Monterey Bay is located in the Oregonian province subdivision of the Eastern Pacific Region (MBNMS 1998 taken from Briggs 1979). A rich cold-temperate flora and fauna characterize this area (MBNMS 1998 taken from Briggs 1979). The Monterey Bay is located on the continental margin within the California Coast Ranges province (MBNMS 1998). It is situated on the Salinian Block, a major structural unit of the earth's continental crust. This block was shifted northward from the southern Sierra Nevada Mountain Range on the Pacific tectonic plate.

In the Oligocene, (23-35 mya), one-celled plants, called diatoms, fell onto the seafloor piling over 1,000 feet high (Press 1998). Their skeletons were combined by time and pressure and then transformed into solid rock. These are the shalebeds off Del Monte Beach which are flat-topped and "honeycombed" with tunnels.

Biotic Communities

Many organisms live within the shalebeds' high, middle and low relief structures. Sea cucumber (*Parastichopus johnsoni*), Bat star (*Aserina miniata*), Encrusting sponge (*Haliclona sp.*), Giant sea star (*Pisaster giganteus*), Giant green anemone (*Anthopleura xanthogrammica*) and China Rockfish (*Sebastes nebulosus*) are examples of species which reside within or near the shalebeds. In addition, mussels (*mytilus sp.*) and rock-boring piddock clams (*Bankia setacea*) dig the "honeycombed" tunnels within the shalebeds (NOAA and MBA 1997).



Bankia setacea

A variety of rockfish species are found within the shalebeds' cracks and crevices. Small species of rockfish are associated with mud and cobble substrata of low relief and large species are associated with high relief structures (Yoklavich 2000) and high numbers of large rockfish are associated with rock ledges, caves and overhangs. These areas provide a natural refuge for the rockfish. It is generally understood that complex rock outcrops of high relief provide shelter and protection (Yoklavich et. al. 2000 found in Bohnsack, 1989 Potts and Hulbert, 1994 among others).

Sebastes miniatus

Potential for Anchor Damage

The shalebeds may experience damage due to vessels dropping anchor on top of the substrate along with the anchor chain dragging along its structures. A variety of vessels have anchored near Monterey Harbor since the 1700s including fishing, recreation, research and military.

According to the Monterey Harbormaster, Steve Scheiblauer, about 50 vessels anchor in the Monterey Bay each year (Scheiblauer 2001). Vessels within 35 – 65 feet and larger anchor off Del Monte Beach. Most vessels prefer to anchor within the harbor because it is a more protected area. Larger vessels prefer to anchor further out from Monterey Harbor.

Lingcod, kelp greenling, cabezon, surfperch and rockfish recreational fishing is very popular in the Monterey Bay (MBNMS 1998). This may result in an increase in the number of anchorages in Monterey, causing additional damage to the shalebeds.

Anchor Types

The type of anchor and size or weight of an anchor depends upon tonnage and length of the vessel and its displacement at maximum load. It is also dependent on the type of bottom and abiotic conditions at time of anchorage (Bamford 1985). Figure 2 is a graph depicting vessel length and corresponding anchors for such lengths.

As the length of a vessel increases, the weight of an anchor also increases. The greater the anchor weight, the greater the potential for damage to both physical structures and biological communities in the shalebeds.

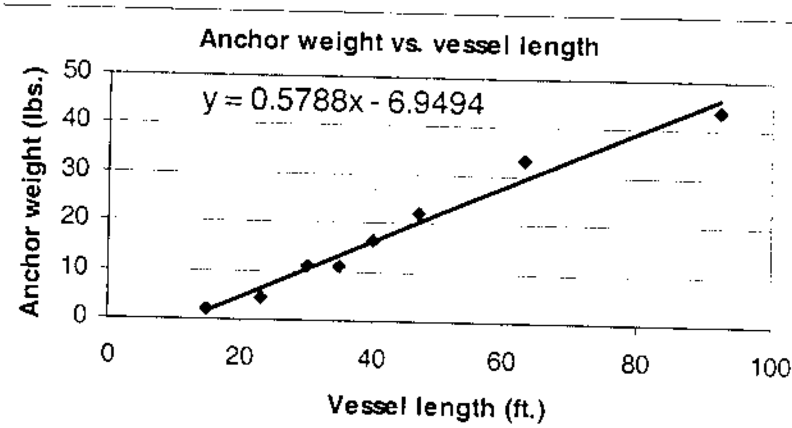


Figure 2. Varying anchor weights according to vessel length. The greater the vessel length, the heavier the anchor (Source: Bamford 1985).

Physical Damage

Vessels with anchors at any weight may cause damage by scouring the surface of the shalebeds. The greater the anchor weight, the greater the potential for damage to the physical structure of the shalebed. An anchor with its chain dropping on top of a shalebed structure may break a high, middle or low relief ledge of a shalebed into a rubble pile. As the size of an anchor and anchor chain increases, the area of the damage under which it drops increases. In addition, if an anchor and anchor chain drag due to wind, ocean currents or vessel motion, additional damage may occur to the relief structures. Furthermore, when anchoring, vessels will expel about five to seven times more chain than depth (USCG 1998). For example, a vessel anchoring at a depth of 60 feet will expel 360 to 420 feet of anchor chain. This additional chain may potentially cause an increase in damage to the shalebeds.

This can further be explained in terms of physics. As the weight of an object increases, the force exerted on a surface increases (Fernandez 2001). Therefore, as the weight of an anchor increases, the force exerted on the physical structure of the shalebeds increases. For example, a vessel of 41 feet in length with an anchor weighing 21 pounds will exert a force of about 90 newtons. A vessel 887 feet in length with an anchor weighing 30,000 pounds will exert a force of about 130,000 newtons. Damage will potentially occur to the shalebed structure because "in the real world, a perfectly rigid body does not exist" (Hecht 1996).

Biotic Damage

A dropped anchor and a dragging anchor chain may cause damage to organisms living within and on the shalebeds. Even without the drag of an anchor or anchor chain, their weight alone will cause some amount of damage to organisms living on top of the shalebeds. As the weight of the anchor and anchor chain increases, the potential for damage to organisms increases. Species such as rockfish are environmentally mobile while others such as anemones are sessile and reside within the shalebeds. The sessile species are unable to move away from approaching anchors and anchor chain.

Questions and Hypothesis

My Capstone will focus on two questions. First, have vessels been using the shalebed area off of Del Monte Beach as an anchoring site? Second, are there alternative locations for vessels to anchor that will minimize damage to the shalebeds? To answer these questions, my general approach was to use GIS and Acoustic Remote Sensing Data to distinguish between high and middle relief areas most susceptible to anchor damage and low relief and sandy areas that satisfy anchoring requirements of vessels. My hypothesis is that there are alternative areas for vessels to anchor that will minimize the amount of damage to the shalebeds.

Methods

To determine if vessels have been using the shalebed area off of Del Monte Beach as an anchoring site, I first contacted the Monterey Harbor Office. The Harbormaster and staff helped to answer my questions concerning where vessels currently anchor in Monterey. I viewed archives and current articles in local newspapers, including the

Monterey Peninsula Herald and the *Monterey Herald* at the Monterey Public Library regarding vessels that have anchored near Monterey Harbor since the 1970s.

To determine if there are alternative locations for vessels to anchor that will minimize damage to the shalebeds, I researched current anchoring criteria. The United States Coast Guard provided me with information on current anchoring criteria. I also studied several books on anchoring techniques and practices.

In addition, I examined a bathymetric map of the Monterey Bay shalebeds off Del Monte Beach created by the Seafloor Mapping Lab at California State University, Monterey Bay. This map aided me in understanding the bathymetry of the seafloor. Ledges, vertical walls and boulders are useful topographic features when determining the structure for the seafloor. This map depicts areas of high, middle and low relief structures of the shalebeds.

I produced a map featuring what I have determined to be the most appropriate areas for anchoring near Monterey Harbor. The map displays areas of high, middle and low relief in the shalebeds and surrounding sandy areas. My objective was to use the current set of criteria from previous research and use my criterion for anchoring in low relief and sandy areas; analyze existing marine habitat maps of the shalebeds; and create a new map displaying ideal anchorage sites using GIS.

In order to determine alternative locations for anchoring near Monterey Harbor, I viewed a high-resolution map of the shalebeds to identify high relief areas that may be more sensitive to anchor damage and low relief areas that may be less susceptible to anchor damage.

Using TNT Mips, I imported a shalebed map and looked for "roughness" in 10 m cells. This map was then converted to an 8-bit raster. Then, a second raster was produced whose value of each pixel was the standard deviation of neighboring 10 x 10 cells. High relief areas had a higher standard deviation and varying values. Low relief had a lower standard deviation and more uniform values associated with them. I used "brightness" as a measure for how "rough" or "shadowed" the relief structures are. I then created three classes of relief in TNT Mips. Class 1 represented low relief and sandy areas and was assigned the color green. Class 2 represented middle relief and was assigned the color yellow. Class 3 represented high relief and was assigned the color red.

In addition, using TNT Mips, I calculated the percentage of low relief and sand, middle and high relief in the shalebeds.

I created several maps in TNT Mips depicting various sites for anchoring. I color-coded the sites according to relief. First, I created a map displaying areas where vessels currently anchor based on interviews with the Monterey Harbor Office (Fig. 2). Second, I created a map displaying areas where vessels anchor based on the set of criteria I researched (Fig. 3). Third, I created a map with red vector polygons displaying areas of high relief in the Monterey Bay shalebeds (Fig. 4). I consider these to be areas where vessels are restricted from anchoring. Fourth, I created yellow vector polygons depicting areas of middle relief (Fig. 5). Fifth, surrounding the restricted high relief and middle relief areas are green vector polygons depicting my choice of acceptable anchorage areas (Fig. 6).

In order to research the diversity of the shalebeds, I viewed underwater videos taken by a diver handheld camera and drop camera of the shalebeds off Del Monte Beach recorded by California State University's Seafloor Mapping Lab. I then created a species list of organisms found within areas of sand, low, middle and high relief.

Results and Discussion

The following table (Table 1) displays current anchoring criteria gathered from interviews with the United States Coast Guard, California Maritime Academy, the Monterey Harbor Office and books:

Reasons for anchoring
Engine failure
Need to stay outside of a breaking inlet or bar
To weather a storm
To hold position while passing gear to disabled vessel
Shelter
An area of sheltered water
The exact place to anchor
The nature of the bottom
The anchor and cable to be used
The length of the scope (length of line between vessel and anchor (Fagan, 1986).
Any necessary further precautions

Conditions
Area protected from waves or swell
Visibility
Wind direction and force
Direction and size of waves and swell
Weather forecast
Distance to alternative shelter
Time of sunset
Length of proposed stay
Special problems
Geographical Zone
Difficulties in the approach
Depth of soundings – according to draft of boat
Characteristics of the tide
Aspects of the land geography
Ease of leaving by night
Anchoring in strong winds
Intensity of the gusts
Sea conditions
Immediate environment
Characteristics of the tide
Equipment available
Basic elements to proper anchoring
Proper equipment availability
Knowledge to use equipment
Ability to select good anchoring areas

Table 1. Current anchoring criteria used by vessels.

Criteria for general areas for anchorage:

- Visibility - Sailors must consider many variables when deciding on where to anchor. Is it night or is there poor visibility? Are buoys or beacons visible? The vessels' searchlight must be able to cut through darkness for two or three hundred yards.
- Wind direction and force – The direction of wind determines the most sheltered area for anchoring. Sailors must consider waves created by wind.
- Direction of waves or swell – This will be determined by the strength of wind, the length of time the wind had been blowing and the extent of the area the wind is acting upon (the fetch). Swell can be from a local wind that has moved away. Therefore,

the direction of the waves that form the swell can be different than the wind at the time.

- Weather forecast - Weather conditions affect sea conditions and conditions can change hourly.
- Distance to alternative shelter – This factor will vary with the time of day, speed of the vessel and extent of alternate route.
- Time of sunset – This also relates to time of day, speed of vessel and extent of route.
- Length of proposed stays – This greatly influences choice of anchorage. If the stay is for a few hours, sailors choose to anchor in an open bay. However, if the vessel will anchor overnight or for a few days, greater security from winds is necessary. According to the Monterey Harbormaster, there is a limit of 30 days for anchoring in the Monterey Bay (Scheiblauer 2001).
- Special problems – These include rigging failure, motor breakdown, lack of provisions and physical accidents are reasons for anchoring as soon as possible.

Criteria describing the exact position where a vessel is to be anchored:

- Difficulties of approach – These include underwater reefs, coastal hazards, offshore rocks and violent currents. An appropriate anchorage location should be a position that can be accurately located. If there is a danger *en route*, sailors will try and pass leeward of it.
- Depth soundings – The draft of the vessel and the variations in depth caused by tide fluctuations determine depth of soundings. For less experienced navigators, (Grec 1981) recommends considering the soundings on the navigational chart to indicate the maximum depth at low water.
- Land geography – The relief of coastline will have a direct effect on wind characteristics. The height of the land will influence strengths of squalls.

Methods for dropping anchor:

- Decide on scope and consider water depth.
- For depths under five fathoms (10 meters), sailors will:
- use three times rope or chain for winds blowing at four knots.

- use five times the depth of water for winds blowing at 22 knots.
- use seven times the depth of water for winds blowing at 40 knots.
- When winds are blowing more than 40 knots per hour, sailors will use two anchors on separate cables (Gree 1981).

Nature of seabed:

- The quality of the bottom is very important when considering where to anchor. It affects the ability of the anchor to dig in and hold. Nautical charts will usually depict the nature of the bottom, whether is be sand, coral, pebbles or boulders. Charts may not describe the holding power of the bottom, such as softness of sand or looseness of mud (Hinz 1986). Sand is the ideal holding ground, except for when it is very soft or very hard (Fagan 1986). An anchor digs in and holds well in firm sand. Rocky bottoms are useless for anchoring (Fagan 1986). For instance, coral causes damage to the anchor and cuts through anchor chain.

Different than land, the seabed is hidden from view. Therefore, bathymetric maps are helpful tools for identifying the nature of the bottom when deciding on where to anchor. Knowing the characteristics of the seafloor will assist in deciding an appropriate anchor location.

In order to determine where vessels currently anchor near Monterey Harbor and if there are alternative, less sensitive locations that would also meet the anchoring requirements of vessels, I created several maps in ArcView and TNT Mips.

Figure 3. Bathymetric maps of the shalebeds off Del Monte Beach.

Figure 4. Current anchoring sites (blue polygon) near Monterey Harbor. Anchoring sites occur above the Del Monte Beach shalebeds.

The blue polygon in Figure 4 was derived from personal communications with the Monterey Harbor Office. About 50 vessels 35 – 65 feet and larger anchor in this area per year. Larger vessels anchor further out from shore. Vessels of all sizes can anchor here ranging from 35 to 1000 feet in length. Several vessels can anchor at a time, as the blue polygon is about 1,300 meters wide and about 1,500 meters long.

Figure 5. Anchoring locations (green polygons) based on current anchoring criteria.

The green polygons in Figure 5 depicting anchoring locations were derived from literature discussing anchoring criteria. Table 2 lists criteria which ship captains use when anchoring. In Monterey Harbor, anchoring locations are based on shelter, weather, atmospheric conditions, geography and length of stay.

Using GIS, I created the following maps depicting three classes of relief. These include high, middle, and low relief and sandy areas in the shalebeds.

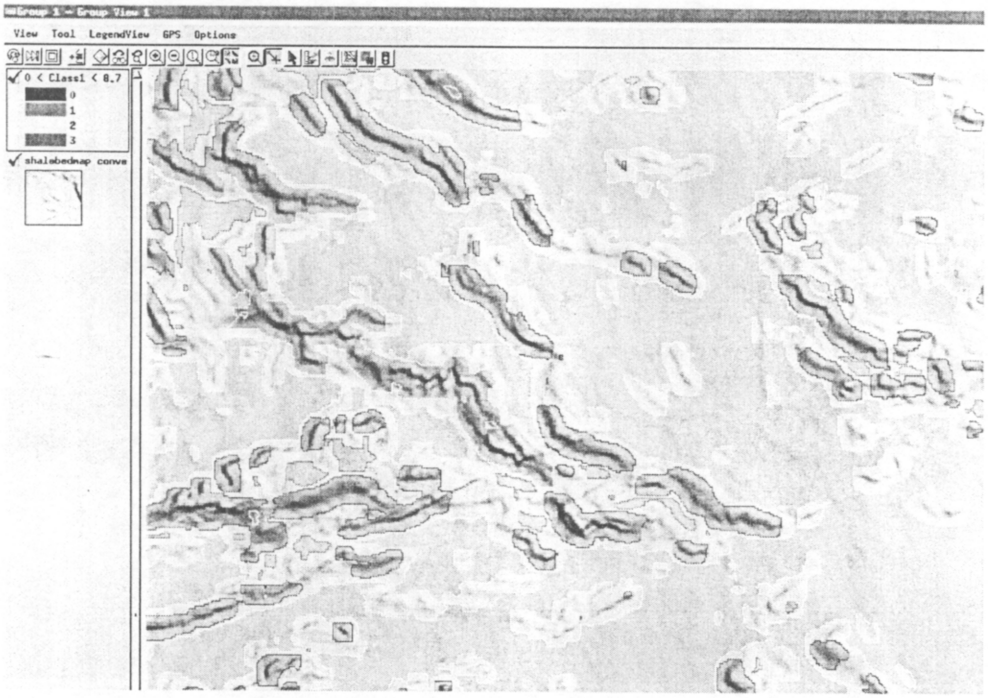


Figure 6. Vector polygons displaying areas of high relief (red).

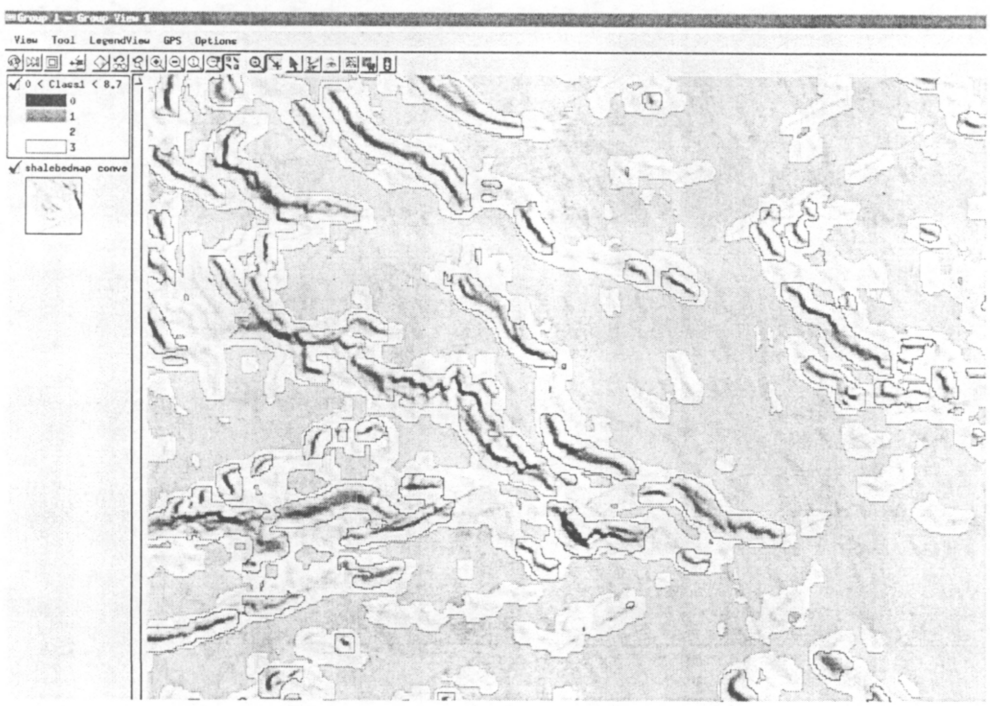


Figure 7. Vector polygons displaying areas of middle relief (yellow).

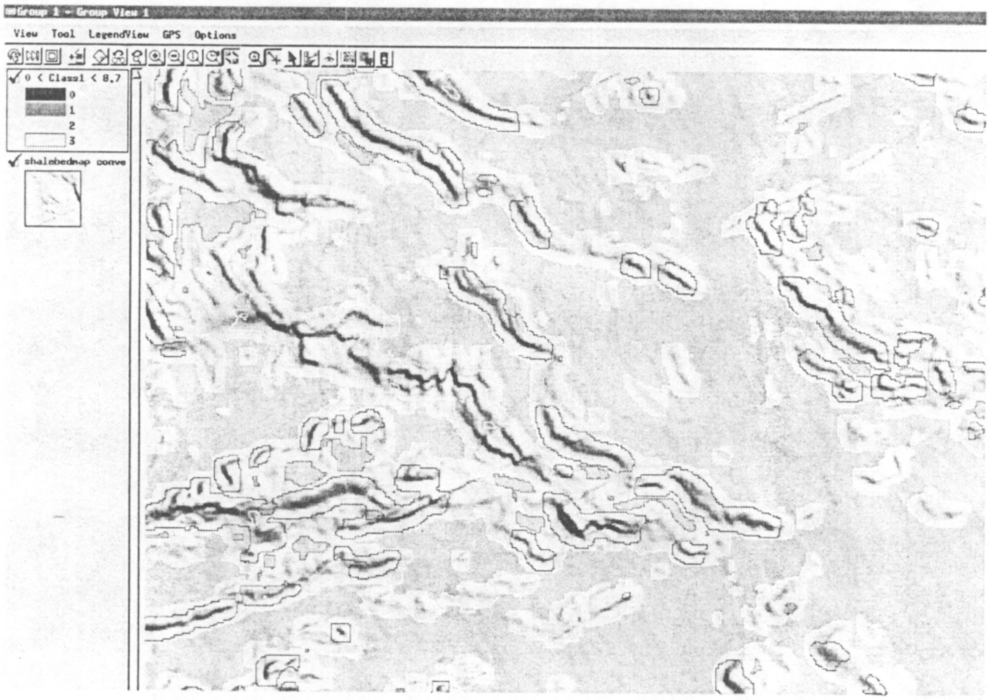


Figure 8. Vector polygons displaying areas of low relief and sand (green).

Figure 6 displays vector polygons which encompass areas of high relief. High relief areas of the shalebeds are of concern because they are home to a variety of organisms. Figure 7 displays vector polygons which surround areas of middle relief. These are areas of moderate concern because they, too, house many different marine organisms. Low relief and sandy areas are depicted in Figure 8. I consider these areas to be more acceptable anchoring locations than middle or high relief areas because there are fewer organisms living within the low relief structures and sandy seafloor.

Figure 9 shows that in the shalebeds, there is a higher percentage of middle relief followed by low relief and sandy areas and high relief.

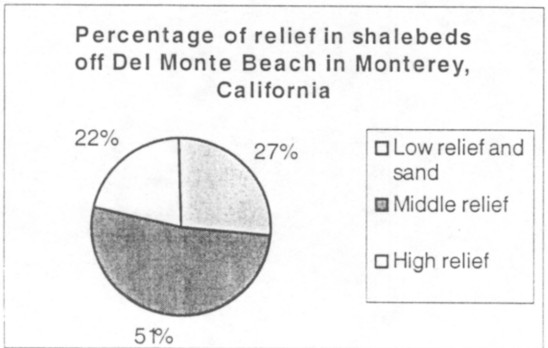


Figure 9. Pie graph displaying percentages of low relief and sand, middle and high relief in the shalebeds off Del Monte Beach.

Table 2 lists species I observed in the shalebeds off Del Monte Beach.

Common Name	Scientific Name	* observed in u/w video	* Location in shalebeds
Painted greenling	*Oxylebius pictus*		**1 Low relief**
Kelp greenling	*Hexagrammos decargrammus**	1	**2 Middle relief**
Lingcod	*Ophiodon elongatus*		**3 High relief**
Vermilion rockfish	*Sebastes miniatus**	1	**4 Sandy seafloor**
Encrusting sponge	*Haliclona sp.*		
Sea cucumber	*Parastichopus johnsoni**	1,2	
Sea star	*Pisaster giganteus*		
Peanut worm	*Themiste pyroides*		
Piddock clam	*Bankia setacea*		
Brittle star	*Ophiothrix spiculata*		
Porcelain crab	*Petrolisthes cinctipes*		
Red algae	*Chondracanthus corymbiferus*		
Red algae	Crustose coralline algae		
Strawberry anemone	*Corynactis californica**	1,2,3	
Bat star	*Aserina miniata**	1,2,3,4	
Data mussel	*Lithophaga plumula*		
Giant octopus	*Octopus dofleini*		
Giant sea star	*Pisaster giganteus**	4	
Rough piddock	*Zirfaea pilsbryi*		
Mussel blenny	*Hypsoblennius jenkinsi*		
Coralline sculpin	*Artedius corallinus*		
Gumboot chiton	*Cryptochiton stelleri*		
Lingcod	*Ophiodon elongatus*		
Scale-sided piddock	*Parapholas californica*		
Wart-necked piddock	*Chaceia ovoidea*		
Barred surfperch	*Amphistichus argenteus**	1,2	
Bocaccio	*Sebastes paucispinis**	3	
Copper rockfish	*Sebastes caurinus*		
Giant feather duster	*Eudistylia polymorpha **	1,2	
Nutting's sponge	*Leucilla nuttingi**	1,2,3	
Red octopus	*Octopus rubescens**	1	
Sunflower star	*Pycnopodia helianthoides**	1,4	
Frilled anemone	*Metridium senile**	1	
Ochre sea star	*Pisaster ochraceus**	1,2,3	
Purple sea urchin	*Strongylocentrotus purpuratus**	2,3,4	
Burrowing anemone	*Pachycerianthus fimbriatus**	4	
Fish-eating anemone	*Urticina piscivora*		
Black surfperch	*Embiotoca jacksoni**	2	
Gopher rockfish	*Sebastes carnatus**	2,3	

Common spider crab	*Libinia emarginata**	3
Coralline bryozoan	*Diaperoecia californica**	3
Blue rockfish	*Sebastes mystinus**	3
Yelloweye rockfish	*Sebastes rubemimus**	3
Black rockfish	*Sebastes melanops**	3
Cabezon	*Scorpaenichthys marmoratus**	3
Compound tunicate	*Didemnum carnulentum**	4
California halibut	*Paralichthys californicus*	4
Sand dollar	*Dendraster excentricus**	4
Jack mackeral	*Trachurus symmetricus**	1,2,3
White-plummed anemone	*Metridium giganteum**	3
Sargo	*Anisotremus davidsoni**	3

Table 2. Species found within sandy areas and low, middle and high relief areas.

Conclusion and Recommendations

Based on research for this Capstone Project, vessels are anchoring on the shalebeds off Del Monte Beach. Additionally, there are alternative locations for anchoring in sandy areas and low relief structures that will minimize damage to the shalebed habitat while meeting current anchoring requirements.

The shalebeds are mostly comprised of middle relief. These areas are home to many marine organisms. By recommending alternative anchoring locations, damage occurring to the organisms within these areas will hopefully decrease.

The Geographical Information System (GIS) information and data that I have gathered will be useful to various audiences. The Monterey Bay National Marine Sanctuary is interested in learning about the possible detrimental affects of anchor damage on the seafloor. In addition to this, the United States Coast Guard and Monterey Harbor Office expressed an interest in receiving a copy of my Capstone. I hope that my Capstone will be considered when marine policy in Monterey is discussed.

The maps I have created may be beneficial to future vessels entering the Monterey Bay because they will provide them with information displaying areas which are the most safe and convenient locations for anchoring. Not all vessels have bathymetric maps displaying the nature of the seafloor. If these maps are considered and implemented, organisms within the shalebeds will be more protected from potential anchor damage.

There may be social and economic implications of this Capstone. For instance, ships may not be willing to abide by my recommended anchoring locations and criterion. Environmental conditions such as strong winds and currents may not allow for ships to anchor over sand. However, I hope that ship captains will be willing to consider my recommendations.

There needs to be more quantitative studies conducted on the effects of anchor damage to sensitive marine ecosystems. I hope that this project will set the groundwork for such studies.

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