INTRODUCTION

The objective of this paper is to provide a brief overview of the natural disturbance regime in subtidal hard substrate habitats of the Gulf of Maine, as background for considering effects of anthropogenic disturbance on these communities. Patterns of benthic invertebrate and algal community structure in these habitats have been described by Sears and Cooper (1978), Hulbert et al. (1982), Witman and Cooper (1983), Witman (1985, 1987, 1996), Sebens (1985, Sebens et al. 1988), Witman and Sebens (1988, 1990), Watling et al. (1988), Ojeda and Dearborn (1989), Vadas and Steneck (1989), and Leichter and Witman (1997). The descriptions will not be repeated here.

Disturbance is defined as a physical or biological process that creates a space suitable for colonization (Grime 1977). Physical disturbances impacting marine communities include storms, hurricanes, landslides, ice scour, low salinity excursions, and unusually large temperature changes (Dayton 1971, Paine and Levin 1981, Wethey 1985, Connell and Keough 1985, Witman 1987, Minchinton et al. 1997, Witman and Grange 1998). Biological disturbances generally refer to the direct or indirect effects of predators or herbivores that remove organisms they consume or dislodge organisms while moving across the substratum (e.g., “bulldozing,” Dayton 1971). In order to understand how disturbance changes an ecological community, it is important to characterize various aspects of the disturbance regime such as the areal extent, intensity, and frequency of the disturbance (Pickett and White 1985). For example, an intense disturbance such as a once-in-a-century storm may create large clearings (patches) that will provide a unique opportunity for colonization, possibly causing large-scale changes in patterns of abundance and distribution of species on the sea floor. A disturbance that is frequent or timed during a specific season would provide a more predictable source of space for colonization, space that could be occupied only by species that produce larvae or asexual propagules in the season of disturbance. In most marine habitats subjected to wave action, the disturbance regime varies greatly with depth. Consequently, I have structured this paper to consider how disturbance and colonization vary from shallow to deep habitats.

PHYSICAL DISTURBANCE

The predominant form of physical disturbance in the Gulf of Maine subtidal is wave-induced water motion. Sponges, sea urchins, sea stars, the mussels Mytilus edulis and Modiolus modiolus, the stalked ascidian Boltenia ovifera, and most species of kelp living at shallow depths are commonly dislodged from hard substrates when hydrodynamic forces exceed the attachment strength of individual organisms during
periods of high water velocity. As a consequence of the near-exponential decrease in wave-induced water velocity with depth (Riedl 1971), physical disturbance is uncommon at depths of 30 m and greater. Depth variation in physical disturbance is reflected in a striking decrease in the maximum area cleared with depth (Figure 1). There is roughly a fortyfold decrease in the size of patches created between the low intertidal at 0 m and the shallow subtidal at 10 m depth. The February 1978 “Groundhog Day Gale” and the October 1991 Halloween northeaster (“The perfect storm” of Unger 1997) were the most severe physical disturbances I have observed over the past 20 years. The Halloween northeaster created multiple clearings up to 44.0 m$^2$ area in the low intertidal zone at East Point, Nahant, Massachusetts (J. Witman unpublished data). Areas previously covered by blue mussels (Mytilus edulis) and rockweed (Fucus sp.) were scoured down to bare rock. These are among the largest patches ever recorded in the intertidal zone (Paine and Levin 1981) and are undoubtedly a rare event since the National Weather Service classified this as the most severe storm of the past century. It appeared that the largest clearing was created by the scouring action of cobbles and boulders that abraded the shore during the exceptional 13-m-high waves breaking against the coast (J. Witman, unpublished observations).

In addition to this spatial pattern of physical disturbance, there is some temporal predictability in the frequency of physical disturbance in the Gulf of Maine since northeaster storms tend to be more common from October to March (National Weather Service, Portland, Maine). However, in a three year study of the effect of storm dislodgment on shallow (<10 m) subtidal communities off southern Maine and New Hampshire, Witman (1987) found that severe episodes of mussel and kelp dislodgment occurred during all seasons.

Physical disturbance is chronic in the shallow subtidal, creating a high frequency of small to medium patches usually less than 1.0 m$^2$. A study of physical disturbance effects on subtidal communities at Murray Rock, a shallow ledge about 5 km off Kittery, Maine, identified two major types of disturbance-generated patches: mussel dislodgment patches and kelp holdfast patches (Witman 1987). The mussel patches were created when horse mussels, Modiolus modiolus, were overgrown by kelp and torn loose from the substratum during storms, leaving patches ranging from 0.025 m$^2$ to 0.45 m$^2$. Clearings created when Laminaria digitata or Laminaria saccharina
kelp plants failed at the holdfast tended to be smaller than mussel dislodgment patches, with an average size of .09 m$^2$ (Figure 1, Witman 1987). The colonization of both types of patches was fairly predictable: kelp settled in the patches and dominated space within a few months after they were created. Horse mussels were not able to recover from storm disturbance by colonizing via larval recruitment in over 10 years of observation (Witman 1987, unpublished observations).

Patches up to 1.0 m$^2$ were observed at 8 to 10 m depth off Star Island at the Isles of Shoals when boulders were overturned during the February 1978 “Groundhog Day Gale” (J. Witman and L. Harris, Univ. of New Hampshire, unpublished observations). This probably represents the maximum size of clearings created by physical disturbance in the shallow subtidal zone.

In contrast to the shallow zone, depths of 30 m or greater rarely experience natural physical disturbance sufficient to dislodge organisms from rock surfaces. Communities at 30 m depth have been monitored for a decade at four sites in the Gulf of Maine—Ammon Rock Pinnacle on Cashes Ledge, Columbia Ledge off Mt. Desert Rock, Gull Rock off Monhegan Island, and Star Island at the Isles of Shoals. The only patches created by storms during this time were a few kelp holdfast patches (< .01 m$^2$) at Ammon Rock Pinnacle (Witman 1996, unpublished data) and several patches created by dislodgment of encrusting bryozoans, Parasemnostrea jeffreysi (Genovese 1996). At 50 m depth, observations are limited to a single site, a rock wall on Ammon Rock Pinnacle. During five years of photographic monitoring (1987 to 1991), no patches created by natural physical disturbance opened up in the community at this site (J. Witman and K. Sebens, Univ. of Maryland, unpublished observations).

**BIOLOGICAL DISTURBANCE**

Like physical disturbance, biological disturbance is a frequent feature of shallow rocky subtidal ecosystems in the Gulf of Maine. There are pronounced differences, however, in the size of patches created by the two forms of disturbance, as well as in the pattern of patch size change with depth (Figures 1 and 2). In the intertidal and shallow subtidal, biological distur-

![FIGURE 3. Rock wall at 30 m depth at Ammon Rock Pinnacle, Cashes Ledge. A. (left) Wide angle photograph of a dense aggregation of the sea anemone *Metridium senile* that originally covered most of the top of the ledge. B. (right) Close-up photograph of a nearby spot in June 1987 showing patches created by nudibranch (*Aeolidia papillosa*) predation on the sea anemones. One nudibranch is visible at left, and the sea anemones are contracted in this photograph. Anemones previously occupied the areas covered with white spiraled masses of nudibranch eggs. Bar below photograph indicates 5 cm. Photographs by Jon Witman.](image-url)
bance by sea urchin and sea star predation opens up much larger areas for colonization than physical disturbance. This is in contrast with terrestrial habitats, where physical disturbance creates larger clearings than biological disturbance (Pickett and White 1985).

Sea stars (*Asterias vulgaris* and *A. forbesi*) remove large areas (e.g., several hundred m²) of blue mussel beds at the intertidal-subtidal fringe (Menge 1979, Hulbert 1980, J. Witman unpublished observations). They are restricted from clearing even larger areas in the shallow zone by wave-induced water motion, which can restrict the abundance of these predators at shallow exposed sites (J. Witman and C. Siddon unpublished data). As a consequence of this hydrodynamic constraint on sea urchin and sea star foraging in the shallowest zone, the largest areas cleared by biological disturbance occur deeper in the subtidal zone, around 4 to 12 m depth (Figure 2). For example, a dense band of *Ciona intestinalis*, consumed a kelp bed measuring over 1000 m² at 8 m depth over four months in 1982 at Star Island, Isles of Shoals (Witman 1987). This large patch remained an urchin barrens or coraline algal flats for several years, then was recolonized by kelp (J. Witman unpublished observations, Harris et al. 1998). Since sea urchins are most common at shallow-to-intermediate depths (i.e., 4 to 12 m), the size of patches cleared by biological disturbance in the Gulf of Maine decreases below this depth range (Figure 2).

Predation by nudibranchs can also open large clearings. Twice in the past decade, large patches on the order of 5 to 10 m² were cleared at 28 to 35 m depth at two sites on Cashes Ledge in aggregations of the sea anemone, *Metridium senile*, by nudibranchs, *Aeolidia papillosa*, preying on the sea anemones (Witman 1996, Figure 3). These two disturbance events caused a major long term shift in the distribution and abundance of benthic invertebrates on large spatial scales at the peaks of Ammen Rock Pinnacle and North Ammen Rock Pinnacle on Cashes Ledge. The patches were colonized by bryozoans (primarily *Crista sp.*) within a year, and the bryozoan-dominated state of these benthic communities has persisted since 1991 (J. Witman unpublished observations).

Cod predation is another agent of patch creation in offshore, hard substrate habitats of the Gulf of Maine (Witman and Cooper 1983). Cod feeding on the network of polychaete and amphipod tubes covering rock surfaces at 30 m depth on Jeffreys Ledge created up to a 5.0 percent increase in patch space over a one-year period (Witman and Cooper 1983). The size of individual cod feeding patches was small, seldom exceeding 0.05 m².

Since offshore rocky ledges at 30 to 45 m depth at some sites in the Gulf of Maine are dominated by sponges (Witman and Sebens 1990, Figure 4), spongivorous predators have the potential to be important agents of space creation in the deep subtidal zone. The blood star *Henricia sanguinolenta* is a spongivore (Sheild and Witman 1993) that occurs in feeding aggregations on the sponges *Mycale lingua* and *Halichondria panicea* at 30 m depth on Cashes Ledge (Shellenbarger 1994). The blood star occasionally consumes an entire sponge, resulting in patches up to 0.2 m² (J. Witman unpublished observations).

We have observed the polychaete *Euphroina borealis* feeding on the sponges *Iophon sp.* and *Halichondria panicea* at 30 to 50 m depth at Ammen Rock Pinnacle, but the role of this predator as a source of patch creation is presently unknown.

### Natural Mortality

Although not a type of disturbance, the natural mortality of sessile invertebrates often opens up space for colonization in deep rocky subtidal habitats of the central Gulf of Maine. Several species of sponges have a well-known tendency to become necrotic and slough off rock surfaces (Bergquist 1978, Aying 1981) releasing a space on the rock surface as large as the sponge. In the Gulf of Maine, populations of the orange mounding sponge, *Myxilla fimbriata*, experience a high degree of turnover due to natural mortality. For example, approximately 25 percent of 200 monitored *Myxilla* sponges turned black, died and fell off rock walls at 30 m depth at Ammen Rock Pinnacle between 1986 and 1988 (J. Witman unpublished data, Figure 4). The average size of these mortality-generated patches ranged from 10 to 50 cm² (0.005 m²). Along with nudibranch predation, sponge mortality is an important process influencing ecological succession in deep rocky habitats by increasing the number of small clearings available for colonization.

Natural clearings or patches rarely occur on hard

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substrates as deep as 50 m (Figure 1). In a five-year monitoring period (1986 to 1991) we observed only two “natural mortality” patches open up on a section of rock ledge measuring approximately 10 m² at 50 m depth on Ammen Rock Pinnacle (J. Witman and K. Sebens unpublished observations). One was caused by the mortality of a sea anemone, Urticina crassicornis, and the other resulted from the death of a large sponge, Mycale lingua.

COLONIZATION
Patches cleared by disturbances may be colonized by the growth of species from the perimeter of the space or colonized from the overlying water column by larvae or asexual propagules (buds, fragments). We initiated a manipulative experiment at 30 m depth at Ammen Rock Pinnacle in 1986 to examine the sequence of colonization by invertebrate species and to test Connell and Keough’s (1985) hypothesis that small clearings in subtidal communities would be colonized primarily from vegetative (asexual) growth of species surrounding the patch. Sponge patches were mimicked by removing 15 Myxilla fimbriata sponges from rock walls (treatments). “Natural” patches in the same size range (20 to 40 cm²) served as the controls, and colonization of both treatment and control patches was followed by close up photography four times over a 15-month interval. The results indicated that the early colonists were two bryozoans, Crisia eburnea and Idhmirolea atlantica, and the serpulid polychaete Spirorbis spirorbis (Figure 5A). Ascidians, (Aplidium pallidum and Aseidia callosa) were later arrivals, occupying on average only 5 percent cover after 15 months (Figure 5B). In over two years of observation, none of the patches was colonized by the sponges that are the major component of the community at Ammen Rock Pinnacle (J. Witman and K. Sebens unpublished data). In contrast to Connell and Keough’s (1985) predictions, all of the patches were colonized by planktonic recruitment. A related study of colonization on artificial hard substrata at 30 to 80 m depth at Ammen Rock Pinnacle found that bryozoans and serpulid polychaetes were the spatial dominants after one year (Sebens et al. 1988). There was a clear trend of increasing bare (noncolonized) space with depth below 30 m, indicating that colonization proceeds more slowly in deeper (50 to 80 m) than shallower (30 m) subtidal habitats (Sebens et al. 1988).

IMPLICATIONS FOR UNDERSTANDING ANTHROPOGENIC DISTURBANCE
There are several summary points about natural disturbance and recovery that have obvious implications for predicting the ecological consequences of anthropogenic disturbance in the rocky subtidal zone of the Gulf of Maine. Benthic communities at shallow depths (< 10 m) are subjected to a high frequency of physical and biological disturbance. The potential for relatively rapid recovery of disturbance-generated clearings in the shallow subtidal is high for some types of assemblages, such as kelp beds, but low for others, like beds of horse mussels, which have not recovered from physical disturbance in over a decade.

FIGURE 4. Area of rocky bottom at Ammen Rock Pinnacle (33 m depth) dominated by sponges. The encrusting sponge is Hymedesmia sp. and the mounding sponge is Myxilla fimbriata. Natural mortality of Myxilla is an important source of space creation in rocky subtidal communities in the Gulf of Maine. Note the sponge at upper left that is black and necrotic. The next photograph in the time series indicated that it fell off the wall, creating a patch the same size as the sponge. Two other Myxilla mortality patches are visible just left of center and at lower right in this photograph. Bar below photograph indicates 5 cm. Photograph by Jon Witman.
FIGURE 5. Colonization of small patches (~ 25 cm²) created by experimental removal of the sponge, *Myxilla fimbriata*, in rocky subtidal habitats at 30 m depth at Ammen Rock Pinnacle. Data represent the mean percent cover of species in 15 patches ± one standard error during the 15 months of observation. All of the patches in Figures 3A and 3B were colonized by larval recruitment. A. Percent cover occupied by two species of bryozoans (*Crisia eburnea* and *Idmidronea atlantica*) and one species of polychaete (*Spirorbis spirorbis*). Note that most of the patch space is occupied by the bryozoans after 15 months. B. Percent cover occupied by the solitary ascidian *Ascidia callosa* and the colonial ascidian *Aplidium pallidum*. Ascidians occupied only 6 percent of the patch space after 15 months of colonization.
of observation. Patches generated by disturbance or natural mortality at 30 m depth are initially colonized by larval recruitment and dominated by bryozoans, which may persist for more than seven years without any return to the natural community dominated by sponges, sea anemones, and ascidians. Large clearings are rarely created naturally in deep (30 m and greater) rocky habitats of the Gulf of Maine. Due to low rates of colonization at depths greater than 30 m, clearings created on deep, hard substrates will take many years to recover whether they are created by natural or by anthropogenic disturbance, such as from fishing gear.

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Bottom Habitat Requirements of Groundfish

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I will address the habitat requirements for commercially important groundfish species and will start by posing the question, what is habitat? A map of northern Georges Bank, for example (Figure 1), shows that it is made up of a series of different types of sediment. The important thing is not the sediment, however, it is the relationship that the animals have with the sediment. Figure 1 shows the relationship between the different life stages of Atlantic cod, Gadus morhua, and the parts of the bank. The life stages of cod, a pelagic spawning fish, begin with eggs and larvae up in the water column. The larval fish settle onto the entire surface of Georges Bank, but because of predation they are very quickly restricted to an area of gravel pavement on the northern edge (Lough et al. 1989; Langton et al. 1996). When they grow larger, they spread out. Adults are widely distributed over the entirety of Georges Bank and move off the bank as well. Each life stage of fish can be considered as a different species because each stage has different requirements and, in particular, each stage relates to the environment on an entirely different scale.

I want to focus on the word scale. Fisheries management often deals with a very large scale. The National Marine Fisheries Service (NMFS), for example, uses a stratified random sampling design in its bottom trawl survey that covers the northwest Atlantic Ocean from Cape Hatteras to the Canadian border. NMFS looks at the northwest Atlantic as a series of discrete strata that are set up to represent the different depth zones in the region and are assumed to be internally homogeneous in terms of fish abundance. Those zones are very large-scale features. Sampling at this scale gives an idea of what the population of fish is doing over an entire area such as the Gulf of Maine. It does not provide much insight into how a fish considers the Gulf of Maine, and that is what I want to do. I want to contrast the large-scale features that are considered for management purposes with the small-scale features that a fish might respond to when it makes its decision on whether to go left or right around a boulder. The large-scale strata used in the bottom trawl survey reflect community structure and aggregations of fish, which are useful for management purposes. But an individual fish might consider the environment quite differently.

It is clear that our perceptions of the sea floor depend on the scale used in sampling. In many places in the Gulf of Maine, every time the intensity of sampling the sea floor is increased, the number of recognized patches of different sediment types increases (Kelley, this volume; Langton et al. 1995). Zeroing in on a smaller area significantly improves the characterization of the area, and few areas have been characterized on a scale that adequately describes the features that fish and other benthic animals associate with.

To summarize the concept of scale, consider the nested diagram in Figure 2. This diagram shows that on a large scale, the scale of the NMFS bottom trawl surveys, temperature and depth are the controlling features. On the next smaller scale there is the sedimentary structure. Within this sedimentary structure,
there are structures such as sand wave fields or fairly large geological features. To start thinking about animals, even smaller scales must be used, scales of tens of square meters or less. Thus within a field of sand waves there are sand wave crests and sand wave troughs. Those are the features that fish actually orient to, and in a trough there might be a series of amphipod tubes with amphipod distribution relating to the actual particle size of the sand.

I have been involved in several studies conducted by the Department of Marine Resources that attempt to elucidate the habitat associations for groundfish in my favorite part of the ocean, the Gulf of Maine. One of the areas that we have focused on is Sheepscot Bay in the midcoast region of Maine. We selected Sheepscot Bay because it is historically known as a spawning area for cod and it is also a nursery for young cod.

One part of the study was a groundfish tagging program in the Sheepscot Bay area from 1978 to 1983 to determine the movements of cod. Out of 4191 cod tagged, we had 255 tag returns from known locations by March 1985. Almost half of the returns came from within the tagging site, and many others came from the adjacent coastal area (Perkins et al. 1997). Although some fish moved out of the area, the important conclusion is that these fish are not randomly or regularly distributed throughout the Gulf of Maine. They have a pattern of behavior that is repetitive and predictable and largely constrained to a limited area. These results parallel the observation of cod highways off Newfoundland by Rose (1993), but they contrast noticeably with the assumption made in NMFS stock assessments that the Gulf of Maine has a single stock of cod. Our tag returns from one location in the Gulf of Maine show a pattern of movement that suggests, instead of random distribution around the Gulf, a distinct coastal population of cod.

One of the reasons cod come into the Sheepscot Bay is because it is a spawning location. There has been a recent effort in Maine to identify historic spawning grounds based on interviews with older fishermen (Ames 1997). That effort has shown that people have known for years about cod coming into Sheepscot Bay. This raises questions of why Sheepscot Bay is important to cod and why fish keep coming back.

We addressed these questions by trawling at several stations in Sheepscot Bay and studying the fish community at each station. Geologically, Sheepscot Bay is a drowned river valley with a mud bottom and a sandy delta that both date to the last Ice Age. Three stations spaced three to four nautical miles apart were repeatedly sampled. Stations A and C...
are in mud, while station B is in gravel. In spite of the proximity of the stations, they contain two dramatically different fish communities (Figure 3; Langton et al. 1995). The six dominant species in the fish community show distinct patterns of distribution that reflect patchiness on a very small scale. The fish that tend to make up the A and C station grouping (the American plaice community) hardly occur at all at station B, while the longhorn sculpin community occurs infrequently at stations A and C, but much more frequently at station B. (For scientific names of the fish species, see caption for Figure 4.)

How can we explain these differences over such a small scale? Stations A and C share not only the same depth zone but also the same substrate type—mud. Station B is in shallower water and has a mixed sand and gravel substrate. Therefore both depth and sediment type may explain the distribution of these fish. We took the study one step further and looked for reasons why the fish occur on each sediment type. Instead of taking grab samples to collect benthic invertebrates at each station, we used fish to collect the samples, which is cheaper and more selective. Fish stomach contents give a pretty good idea of what a fish is eating. A particular amphipod occurred much more frequently in the stomachs of fish caught predominantly at station B (longhorn sculpin, winter flounder, yellowtail flounder, and little skate) than in the stomachs of fish caught predominantly at stations A and C (American plaice and ocean pout) (Figure 4). The fish are not just zeroing in on depth, they are not just zeroing in on sediment types, but they are zeroing in on lunch!

Next we looked at the amphipod and asked why it is there. The amphipod, *Unciola inermis*, is a tube dweller and is there because the area has the right size gravel to build its tube. Furthermore, at station B, there is a gradation from sand to gravelly sand. We
took samples, using a mechanical grab sampler, and we compared the number of amphipods with sediment type over a series of months. We found that this little amphipod occurred much more often in the gravel component of that station (Langton unpublished data).

What we have discovered when looking at the appropriate scale, i.e., a fish eye view of the world, is that the fish are occurring at station B because of prey that is dependent upon the substrate type for its existence. Thus ratcheting the scale down from the population level to the level of the individual fish starts to explain the fish’s relationships with habitat. They are very complex, but they are also very interesting. Throughout the Gulf of Maine there are similar habitats to Sheepscot Bay.

Not only is there a habitat requirement that is dependent on depth and temperature in Sheepscot Bay, but there may be a relationship that depends on time. I have looked at the occurrence, or the catch rate, of winter flounder and longhorn sculpin together with the occurrence of the amphipod over slightly more than a year. As the amphipod population builds up over the year, there is also an increase in the occurrence of these two fish species. The fish move out before a crash occurs in the amphipod population, but as the amphipods build up again the next year, the fish start to reappear (Langton unpublished data). Perhaps there is a time component that we might want to consider when we consider habitat. I mention that, simply because spawning closures are often proposed for managing groundfish, and perhaps we need to think about more than just the spawning fish.

I will conclude with a few comments about where we have been with habitat and where we might go in the future. I think that all of us, scientists in particular, must sit back and look at what we already knew 100 years ago. An example of that understanding is a map drawn in 1887 charting North American fishing grounds and then revised in 1929 by Walter Rich specifically for the Gulf of Maine (Figure 5). There are locations where fish aggregated in the past and continue to aggregate now. These are areas where fishermen are fishing (or at least were). This offers the scientific community the opportunity to ask the same questions I have addressed in the Sheepscot area, why is the Kettle Bottom, for example, a productive area? What is going on out there that makes this an area fishermen continue to fish year after year?

Once we have decided that an area is very important for the sustenance of a particular species, what should we do with this kind of habitat? One suggestion is to set aside these areas as reserves. The rationale for reserves is to protect the benthic community, which in turn nourishes the fish population. The overflow from the reserve provides fish to catch outside of the protected area.

Another possibility is to take an area such as Sheepscot Bay, that we know has been very productive for cod in the past, and put buckets of fish back into the ocean. The Department is currently asking whether or not we can reestablish populations of fish that have a pattern of reoccurrence in Sheepscot. We have recently released a small number of hatchery-
FIGURE 5. Historic fishing grounds in the western Gulf of Maine. Modified from Collins and Rathbun (1887) by Rich (1929).
raised juvenile cod into the Sheepscot, and we are offering an exorbitant reward of $50 for the first one that somebody catches and returns to us. I do not expect to be paying out $50, but I would be more than happy to if we could demonstrate that this is a feasible approach for use in the future, to help restore fisheries.

When we think about fishing and about habitat, it is necessary to realize that the kind of gear being used today to catch the majority of fish is not habitat selective. The bottom trawl is a very good integrator of habitats. We should appreciate the scale at which any fishing gear works, relate that to the way that the animal thinks and hopefully come up with an appreciation of the ecology of the area. If we want sustainable fisheries, we should realize that we are constrained by the ecology of the area, not by our ingenuity in catching fish. We are very effective at developing harvesting technology, but now we must begin to understand habitat relationships with the same ingenuity that we have used in the past to catch fish. We still have the opportunity to do this. We do not yet apply an agricultural mentality to ocean productivity, as is done in some other parts of the world. There is a lot of natural habitat left in New England, and if we start to understand the complexities of it, I believe that we will start to have sustainable fisheries into the future.

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