Coral Reef Restoration

Lily Clark
Gillings School of Global Public Health
Dept of Environmental Sciences and Engineering
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Importance of Reef Ecosystems

- "Tropical rain forests of the ocean"
  - Cover 0.2% of ocean floor but contain 25% of ocean species (1)
- 1/3 of all marine fish species spend a part of their life cycle on or near reef habitats (2, 14)
  - 40% of commercial fish use reefs to breed (14)
  - Provide 6 million metric tons of fish catch annually
- Contribute $30 billion annually to economies worldwide (3)
  - Fishing
  - Tourism and recreation
  - Biodiversity
  - Coastal protection from extreme weather events, tsunamis
- Regulate carbon dioxide in water (1)
- Possible source of new pharmaceuticals

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Reef Destruction: Rates

- 1/3 of the world's coral reefs have been destroyed since the 1960s (4)
  - Predicted to be 60% by 2030
- Caribbean (5, 15)
  - 80% decline in live coral since 1977
    - Live coral cover on reefs declined from 50 to 10%
  - 3-6% annual decline in fish populations since 1990s
  - Elkhorn, staghorn and fused-staghorn coral have declined 80-98% over last 30 years
- Indo-Pacific region (4)
  - Contains 75% of the world's coral reefs
  - Average coral cover declined from 40% to 20% over 25 years
  - Phillipines: only 5% can be considered in good condition

Reef Destruction: Causes

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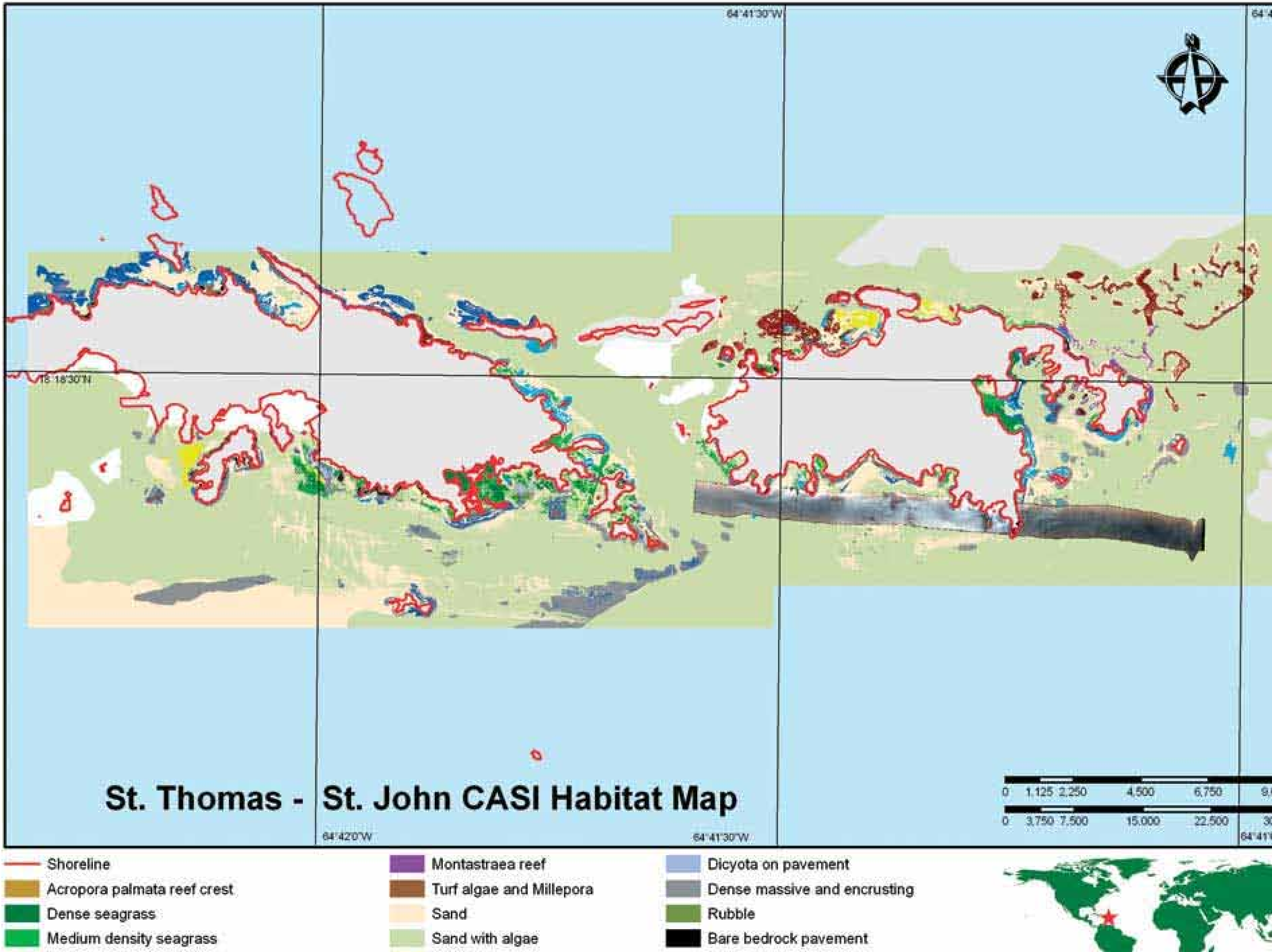
- Anthropogenic disturbances
  - Pollution
  - Fishing
  - Coastal development (sedimentation, eutrophication)
  - Physical destruction (anchors, scuba diving, ship grounding)
  - Invasive species
- Climate change
  - Increased ocean temperatures
  - Ocean acidification due to atmospheric CO2
- Coral disease (6,7)

Reef Destruction: USVI

- U.S. Virgin Islands contain 600 sq km of coral reefs
- Live coral cover has declined from 25% in 1989 to 10% in 2001 (though varies greatly by location) (9)
  - Algae cover has increased from 3% to nearly 35% in the same time period
- Overfishing main threat to reefs - 85% of reefs threatened
- Also marine-based pollution, tourism, coastal development and waste disposal
- Natural disturbances (8)
  - Hurricanes David and Hugo (1979 and 1989)
    - Elkhorn coral cover fell from 85% in 1976 to 0.8% in 1990 due to combination of storms and coral disease
  - Bleaching episodes (1998) – nearly 50% of all corals affected


St. Thomas - St. John CASI Habitat Map
64°41'30"W
18°18'30"N
64°42'0"W
64°41'30"W
0 1,125 2,250 4,500 6,750
0 3,750 7,500 15,000 22,500
Shoreline
Acropora palmata reef crest
Dense seagrass
Medium density seagrass
Montastraea reef
Turf algae and Millepora
Sand
Sand with algae
Dicyota on pavement
Dense massive and encrusting
Rubble
Bare bedrock pavement

Natural Recovery of Reefs

- Natural recovery takes anywhere between 5 years to several decades (6, 7)
  - Dependent on sexual reproduction of surviving coral and settlement of fragments of coral from other reefs
  - If environmental conditions are conducive, degraded area is small, and no physical impediments to recovery
  - Must remove chronic anthropogenic impacts and limit other stressors
  - Must have stable base for coral growth (no sustainable growth on loose rubble)
  - Extensive damage may prevent any possible natural recovery
- Example: Great Barrier Reef, 2009 (10)
  - Unexpected natural recovery following bleaching event in 2006
  - High regrowth of fragments of surviving coral tissue
  - Unusual seasonal die-off of seaweeds
  - Competitive coral species outgrew seaweed

Coral Reef Restoration

- Intended to assist and speed-up natural recovery process (6)
- Projects implemented by governments, nonprofits, volunteer organizations
- Assist in rehabilitation, restoration and remediation of coral reef ecosystems
- Ranges from passive management of human activity (such as land-use restrictions) to active transplantation
- Two types
  - Physical
  - Biological

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Physical Restoration

– Placement of man-made objects in the ocean (6)
  – On the sea floor
  – In the water column
  – Floating on the sea surface

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– Focus on engineering physical reef structures
  – Replace corals as natural barriers
  – Provide a base for re-growth of coral reef
  – Increase public awareness of reef destruction

Examples

- Concrete Reef Balls
- Ceramic settlement plates
  - Mimic branching coral
- Subway cars
- Old tires
- Steel structures
- Wire grids with golf tees

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Physical Restoration: Pros

- Assist and accelerate natural recovery of reefs (6)
- Provide tourist attractions to increase public awareness
- Increase recreational opportunities to boost economy
- Enhance fish diversity and stock
- Reduce pressure on natural reef habitats by providing an alternative area for fishing, snorkeling, scuba diving, etc.
- Provide topographic complexity
- Discourage certain types of fishing

(trawling, seine net) that cause reef damage

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Physical Restoration: Cons

- Costly (6)
  - Major physical restoration $100,000-$1 million per hectare
- Sunken items may contain toxic chemicals and pollutants that leak out into the reef environment
- Can disrupt natural recovery processes
- Unintended and unknown biological consequences
- Could displace naturally occurring species
- Could lure fish populations away from natural habitats
  - More vulnerable to over fishing
- Could be exploited as waste disposal activity ("underwater junkyard")

Biological Restoration

- Assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (6)
- Several different levels of restoration
  - Indirect management to assist in natural recovery
    - Pollution control, fishing restrictions
  - Active restoration such as coral transplantation
    - Incredibly important not to damage existing corals near site of transplantation or used as sources of transplants

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Coral Transplantation

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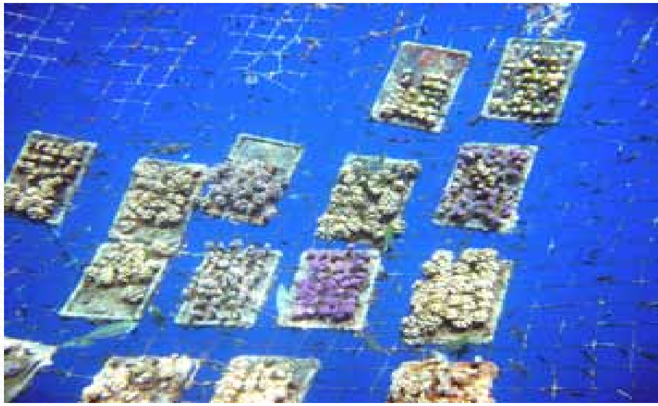
- Often implemented along with physical restoration
  - For example, gluing live coral to golf tees on a wire grid
- Greater survival rates with increasing age and size of the transplant
- Important to minimize stress to corals
  - Sunlight and exposure to air most important
  - Transplantation and subsequent growth is difficult
- Choose appropriate species to enhance probability of success
  - Sea urchins to prevent algal overgrowth

Sexual vs. Asexual Transplantation



- Sexual
  - Larvae collected and reared in nurseries
  - Advantages
    - Doesn't harm the source coral
    - Provides for greater genetic diversity
- Asexual
  - Corals are able to regenerate from small fragments broken off of living corals
  - Fragments of coral are reared in situ (in ocean) or ex situ (in aquariums)
  - "Corals of opportunity" – corals that naturally break off due to weather, physical destruction
    - Have low chance of survival in open water
    - No additional harm to source coral if used in asexual transplantation

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Pros and Cons

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- Pros
  - Speed up natural recovery
  - More directed than simple physical restoration
  - Often quite successful when combined with community conservation efforts
- Cons
  - Cause damage to source coral as well as corals near transplantation
  - Can upset ecosystem if choose wrong species
  - Requires active community participation
  - Costly

Example: Florida (1972)

- Attempt to create an artificial reef off the coast of Fort Lauderdale in southern Florida (11)
- Supposed to be the world's largest artificial reef
  - Composed of more than 2 million tires fastened together with metal clips
- Tires became loose during a series of tropical storms and have been rolling around on the ocean floor
  - Destroying natural reefs
  - Polluting the water
  - Washing up on shore
  - Resting near natural reefs and blocking coral growth

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- Little sea life formed on the tires
- Most US states have stopped using tires as artificial reefs due to this failed project

Example: Mona Island, Puerto Rico

- Ship grounding in 1997 on fringing coral reef (12)
- 6.8 acres restored within months of the grounding
- Reattached branches of coral that were dislodged during incident using wire
- Stabilized over 1,857 coral fragments
- 57% survival after 2 years

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Example: Fiji (2005)

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- Attempt to restore reefs degraded by bleaching in 2002 (6)
- 3 methods of transplanting coral sourced from nearby reefs
  - Plug-in – inserting fragments into rock crevices
  - Place-on – larger colonies placed on rubble patches and stabilized
  - Cement – attached to rocks with cement
- Important to protect transplants from direct sunlight and exposure to air during transport
- Over 95% survival of transplants after 6 months
- However, bleaching event 9 months after transplantation caused death of 2/3 of transplants
  - Nearby natural corals suffered much less
  - Transplants are more vulnerable to stressors

Other options: Mangroves

- Importance of mangroves (13)
  - Reduce and filter sediments and pollutants
  - Stabilize soil and prevent erosion
  - Protect land from storms and floods
  - Provide nursery grounds, shelter and food for coral fish populations
- Restoration is labor intensive, but relatively inexpensive and often successful
- Successful restoration in St. Croix, USVI (1997)
  - 100% destruction by Hurricane Hugo
  - Replanting of red and black mangroves
  - 37% survival using encased seedlings

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Who's Involved?

Focus is often on monitoring coral reef declines in addition to reef protection and restoration

- U.S. Department of the Interior
  - Coral Reef Task Force
- National Oceanic and Atmospheric Association
  - Coral Reef Conservation Program
  - Coral Health and Monitoring program
- Non-profits
  - Reef Balls
  - Coral Reef Alliance
- International Organizations
  - International Coral Reef Initiative
  - Global Coral Reef Monitoring Network
  - International Coral Reef Action Network
  - Caribbean Coral Reef Institute (research)

Should we restore reefs?

- Must carefully consider if active physical and/or biological restoration interventions are feasible and appropriate to the area
  - Analyze potential for natural recovery
  - Ensure no further damage to source coral or surrounding coral habitats
  - Include provisions for reducing human impacts, reestablishing herbivore balance, and improving water quality and environmental conditions
- Must be implemented along with conservation and protection efforts to limit future anthropogenic disturbances
  - Often active restoration harmful due to faulty planning
  - Coastal management and conservation should be the preferred option

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