

Final Restoration Plan for Rose Atoll National Wildlife Refuge

(Including Environmental Assessment)



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and

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March 2001

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Executive Summary

In October 1993 the *Jin Shiang Fa*, a Taiwanese fishing vessel, ran hard aground on the western reef of Rose Atoll National Wildlife Refuge (NWR). The vessel broke up before a salvage tug could reach the atoll, resulting in the release of over 100,000 gallons of diesel and lube oil across the reef. The spill killed a large area of the primary reef building organisms, crustose coralline algae, near the wreck site. Invasive species of cyanobacteria and articulated coralline algae immediately began colonizing those areas of the reef injured by the spill. Data collected in the years following the spill indicates that iron released into the water from corroding metal wreckage is stimulating the growth of the invasive 'weedy' species, thereby preventing resources injured by oil from returning to baseline conditions. These 'weedy' species have spread to areas of the atoll that initially were unaffected by the incident, overgrowing and killing the crustose coralline algae below. Other documented spill-related injuries included the death of numerous giant clams, sea cucumbers and sea urchins. Studies also showed that the composition of the local fish community was altered by the incident.

Since the oil spill, conditions on the reef have continued to deteriorate and there is an increasing likelihood that the very structure of the atoll will become seriously weakened in those areas where the invasive species have replaced the reef building crustose coralline algae. The Natural Resource Trustees (Department of the Interior represented by the Fish and Wildlife Service and the Government of American Samoa) have serious concerns that if the reef is weakened further by the lack of a healthy reef building community, it may be breached, resulting in a significant change in water circulation patterns across the atoll, and the eventual destruction of Rose and Sand Islands. If these islands are destroyed, it would mean the loss of the most important resting and nesting habitat for federally protected seabirds and the federally listed green sea turtle in the American Samoa archipelago.

The goal of the Natural Resource Trustee's (Trustees) Restoration Plan is to stop the ongoing, spill-related injuries to the atoll, thereby permitting the natural resources of the atoll to return to their baseline condition. The large area of crustose coralline algae initially killed by the oil spill has failed to return to baseline levels due to the spread of invasive 'weedy' species. Various marine invertebrates injured by the oil also have failed to return to baseline levels in the six years following the spill. Furthermore, the area of crustose coralline algae injured has expanded due the spread of the invasive species. Emergency restoration actions taken in July-August 1999 and April 2000 indicate that removal of metallic debris will arrest the spread and dominance of the invasive 'weedy' species. The Trustees have concluded that the only way to halt the ongoing injury, caused by the *Jin Shiang Fa* oil spill, is to remove the remaining vessel debris. The removal of vessel debris also is considered a prerequisite to implementing any other restoration alternative.

The Restoration Plan for Rose Atoll NWR consists of removing the remaining vessel debris and monitoring the recovery of the injured reef community. Because of differences in removal techniques, the salvage effort will be divided into three separate operations. The vast majority of the metal debris on the reef flat has recently been

removed by hand and the remaining removal will not require the use of underwater salvage equipment. Larger debris on the reef slope must be cut into smaller pieces by salvage divers and transported to the surface before being loaded onto a vessel for transport to an approved offshore dumpsite. The removal of the remaining lagoon debris also will require salvage divers, who will transport the debris to a smaller salvage vessel stationed within the lagoon and then to the offshore dumpsite. Monitoring will begin after salvage efforts are complete, and will be conducted biennially for the following ten years. The Natural Resource Trustees have estimated the total cost of this operation to be \$1,308,313.

Public comments were sought on the Draft Restoration Plan for Rose Atoll NWR. No public comments were received by the Trustees. The Trustees subsequently adopted the proposed restoration project and issued a Finding of No Significant Impact.

NEPA Compliance

The restoration of natural resources under OPA must comply with National Environmental Policy Act (NEPA) regulations (40 CFR 1500 et seq.). The Trustees used information gathered during several years of assessing injury at Rose Atoll to determine whether an Environmental Impact Statement (EIS) would be required prior to the selection of the final restoration alternative. This Draft Restoration Plan serves as an Environmental Assessment by describing: 1) the need for the proposed restoration action, 2) the environmental setting, and 3) the restoration alternatives along with their potential environmental consequences. Subject to the receipt of new information, including that which is provided by the public, the Trustees do not believe that the proposed restoration alternative will significantly adversely affect the quality of the environment and, therefore, does not require an Environmental Impact Statement.

The Need for Restoration Actions

Data collected at Rose Atoll NWR in the years following the 1993 *Jin Shiang Fa* oil spill indicate that conditions on the reef are deteriorating. The oil spill killed a large area of crustose coralline algae, which was quickly colonized by invasive opportunistic species (U.S. Fish and Wildlife Service [USFWS] 1997). Six years later, these invasive species continue to dominate in the spill zone and have spread to other areas of the atoll, overgrowing and killing otherwise healthy portions of the reef. The Trustee's preliminary field data indicate that the bloom of these invasive species is being artificially maintained by elevated iron levels in the water coming from the corroding vessel debris (Maragos 1999). These data also suggest that the reef area injured by the oil spill will not return to baseline conditions until these invasive species are brought back to baseline levels.

There is an increasing likelihood that the structure of the atoll may become seriously weakened in those areas where invasive species have replaced the reef building crustose coralline algae for several years. If an area becomes so weak it is breached, a significant change in water circulation patterns across the atoll likely would occur leading to the eventual destruction of Rose and Sand Islands. If these islands are destroyed, it would mean the loss of the most important nesting and roosting habitat for federally protected seabirds and the federally listed green sea turtle in the American Samoa archipelago. The preferred restoration alternative proposed in this plan will prevent additional injury to the reef community by returning the invasive species to baseline levels and allowing reef organisms to return to baseline conditions.

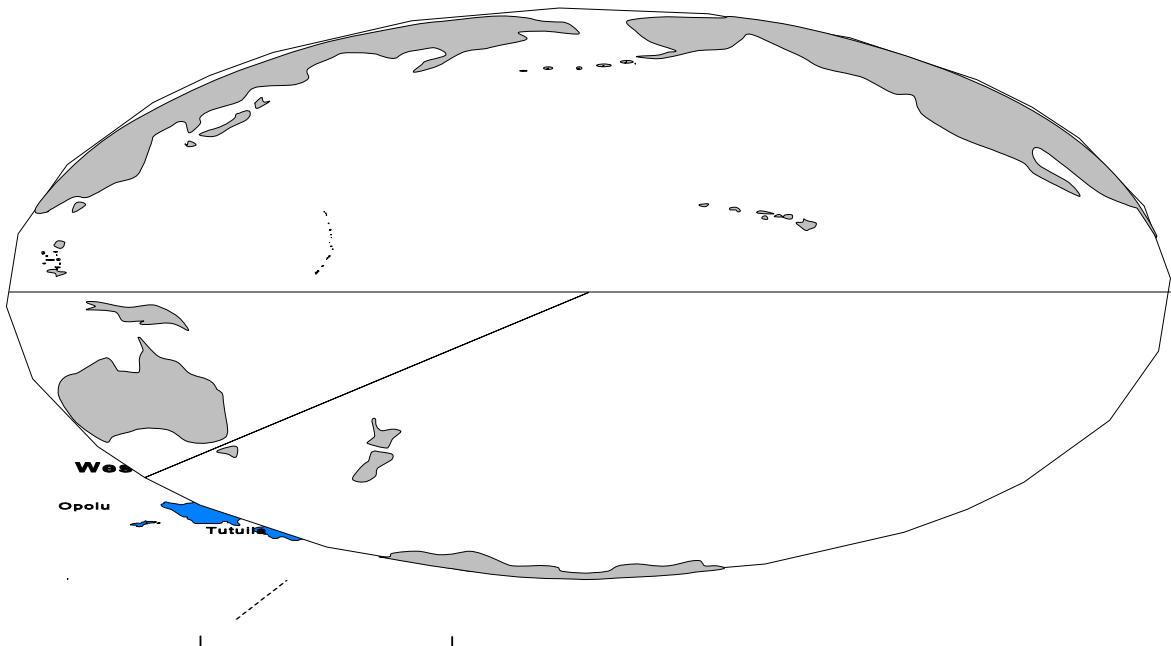
Public Participation

The Trustees considered public review of the Draft Restoration Plan for Rose Atoll NWR to be an integral part of the restoration planning process. Current information was provided about the nature and extent of the natural resource injuries identified and the restoration alternatives evaluated. Public comment was sought on the assessment of natural resource injuries and the restoration project being proposed to restore injured natural resources or replace lost resource services.

A Notice of Intent to Conduct Restoration Planning was published in the Samoa Post on February 24, 2000. A public notice regarding the opportunity to comment on the draft plan was placed in the Samoa Post on April 16, 2000. Public comments were accepted over a period of 30 days until May 15, 2000. The draft plan was made available to the public as part of the publicly-available Administrative Record or in hardcopy form by request. Public review of the Draft Restoration Plan for Rose Atoll NWR was consistent with all federal and state laws and regulations that apply to the Natural Resource Damage Assessment Process, including Section 1006 of the Oil Pollution Act (OPA), the OPA regulations, the National Environmental Policy Act, as amended (42 USC 4371 *et seq.*) and its implementing regulations (40 CFR Parts 1500-1508).

The Trustees received no written comments on the draft plan. Additional information on the status of initial reef cleanup actions and resulting impacts on the reef community was provided by Dr. James Maragos, USFWS (2000) and incorporated into this document. The Trustees, therefore, determined that the Draft Restoration Plan for Rose Atoll NWR could be adopted as a final plan without modifications to the proposed project. The Trustee resolution to adopt the proposed restoration project is provided in Appendix C. A Finding of No Significant Impact determination was made by each of the Trustee agencies. Copies of this determination are provided in Appendix D.

Rose Atoll is located on the far eastern edge of the Samoan Archipelago (Figure 1). The shape of the atoll is square, with the four "corners" facing roughly north, south, east, and west. The lagoon is almost entirely enclosed by the reef, except for a narrow opening on the northwest side (Figure 2). Prior to the *Jin Shiang Fa* oil spill, the atoll was considered to be one of the least disturbed coral atolls in the world (UNEP/IUCN 1988). The unique coral reef ecosystem at Rose Atoll is dominated by crustose coralline algae rather than hermatypic corals more commonly found in the Samoan Archipelago (Mayor 1921, Green 1996). Dominant coral genera at Rose Atoll include *Favia*, *Acropora*, *Porites*, *Montipora*, *Astreopora*, *Montastrea* and *Pocillopora*. Two species, *Favia speciosa* and *Astreopora myriophthalma*, are much more abundant at Rose Atoll than elsewhere in Samoa (Maragos 1994). In contrast, four genera (*Pavona*, *Galaxea*, *Leptastrea*, and *Platygyra*) are less abundant at Rose Atoll than they are on the other islands in the archipelago (Maragos 1994).



Although a "coral" atoll dominated by crustose coralline algae is not unique in the central Pacific Ocean, Rose Atoll is an excellent example of this type of reef. Rose Atoll was designated as a National Wildlife Refuge in 1974 "for the conservation, management, and protection of its unique and valuable fish and wildlife resources" (Greenwalt 1974). Soon after, a Presidential Proclamation recognized that "the submerged lands surrounding Rose Atoll are necessary for the protection of the atoll's marine life, including the green sea and hawksbill turtles" (Ford 1975). This remote refuge is jointly administered by the U.S. Fish and Wildlife Service (USFWS) and the Department of Marine and Wildlife Resources (DMWR) of the American Samoa Government.

The fish community at Rose Atoll also is distinctly different from those that occur elsewhere in the Samoan Archipelago (Green 1996). Fish density is very high and species richness is moderately high at Rose Atoll, although fish biomass is low because of the dominance of small, planktivorous species (Green 1996). The fish assemblages at Rose Atoll also differ from the rest of the archipelago by having a much lower diversity of herbivorous species (especially parrotfishes and damselfishes), and a high density of planktivorous and carnivorous species (primarily damselfishes, unicornfishes, and snappers) (Wass 1981a, Green 1996, unpubl. data). Giant clam (*Tridacna maxima*) densities at Rose Atoll are much higher than elsewhere in the Samoan Archipelago, where populations have been severely reduced by over-harvesting (Green and Craig 1996). Clam density is highest on the atoll at the base of the lagoon pinnacles (Wass 1981b, Radtke 1985, Green and Craig 1996).

Rose Atoll supports two emergent islets, the largest of which (Rose Island, 5.2 ha [12.8 acres]) is heavily vegetated with *Pisonia* trees and beach heliotrope shrubs (*Tournefortia argentea*) (USFWS 1996a,b). Rose Island is an important nesting site for 12 species of federally protected seabirds. Approximately 97% of the total seabird population of American Samoa resides on the atoll (Amerson *et al.* 1982, Rodgers *et al.* 1993, USFWS 1996a,b). Five species of federally protected migratory shorebirds and one species of forest bird use the terrestrial habitat, shoreline, and exposed reef for feeding, resting, and roosting (USFWS 1996a,b). The second island (Sand Island) is smaller (2.6 ha) and unvegetated. Both islands are uninhabited and are important nesting sites for the threatened green sea turtle (*Chelonia mydas*) (Rodgers *et al.* 1993). Satellite tags attached to nesting green turtles at Rose Atoll have shown that these turtles migrate between American Samoa and other Pacific island nations including Fiji and French Polynesia (Balazs *et al.* 1994). In addition to the migratory breeding population of turtles that use the atoll during the nesting season (from August to February), there also appears to be a small, resident population of juveniles living on the atoll (G. Balazs, pers. comm.). Endangered hawksbill turtles (*Eretmochelys imbricata*) also have been seen in the lagoon (USFWS 1996a). It is not known if they nest on the islands.

The coral reefs at Rose Atoll can be divided into seven habitat zones, which vary in terms of their physical and biological characteristics (Figure 2). The **outer reef slope** is located on the seaward side of the atoll, and consists of an irregular and often steep slope down to a depth of approximately 50 meters (m). In some locations, a shallow reef terrace (< 10 m deep) is located on the upper slope, before the reef plunges down almost vertically into very deep water. Spur and groove formations occur on the shallow reef terrace in some locations. The **reef flat** is a hard, consolidated substratum that is exposed during spring tides. The seaward edge of the reef flat, just before the reef starts to slope down into deeper water, is called the **reef margin**. The lagoon is almost entirely enclosed by the reef flat, except for a narrow channel on the northwest side. The inner edge of the reef flat slopes down to a shallow shelf (1-3 m deep) that surrounds the lagoon called the **lagoon terrace**. Most of this shelf (50-75%) is covered with rubble and a few scattered colonies of *Acropora*; the rest is dotted with small patch reefs whose tops are uncovered at low tide. The inner edge of the lagoon terrace

slopes steeply down the **lagoon slope** to the **lagoon floor** (> 15 m deep). The lagoon has an undulating sandy floor with a few isolated *Acropora* patches around its perimeter and numerous flat-topped, vertical **patch reefs** that extend up to the surface and pinnacles submerged below the surface. Wave exposure is low in the lagoon and high on the outer reef slope and reef flat.

Sand Island

outer reef slope reef margin reef flat lagoon terrace lagoon slope lagoon floor pinnacles & patch reefs lagoon floor

Oil Release

At approximately 4:00 am on October 14, 1993, the Taiwanese longline fishing vessel *Jin Shiang Fa* ran hard aground on the seaward edge of the southwest arm of Rose Atoll NWR. The ship had just refueled in Pago Pago Harbor on Tutuila Island less than 24 hrs earlier and was in transit to an unspecified fishing area in the Pacific (USFWS 1996a). Initial observations of the wreckage suggest that the vessel was traveling parallel to the southwest arm when it struck the reef. The vessel collided with the upper portion of the outer reef slope and skipped across the tops of two large spurs (depth 3-4 m) before coming to rest on the tops of two others. The orientation of the grounded vessel was nearly parallel to the reef margin, with the ship's hull keeled over toward its port side and its bow pointed in a north-northwesterly direction (Molina 1994).

At the time of the grounding, the 37 m vessel was carrying approximately 100,000 gallons of diesel fuel and 500 gallons of lube oil. All of these contaminants were discharged into the marine environment at the wreck site where prevailing currents carried the bulk of the material across the reef flat and into the lagoon. The rate at which the contaminants were released into the marine environment could not be accurately determined, although the discharge appeared to be continuous for approximately six weeks after the initial grounding. Based on observations during over-flights and site visits, the majority of the oil likely was discharged within the first few days after the grounding, with lesser amounts discharged up until the time of salvage operation six weeks later (Barclay 1993, Molina 1994, USFWS 1996b).

Due to the heavy wave action at the atoll, it is likely that a significant portion of the fuel oil moving over the surf zone was forced downward into the water column and trapped in the reef structure. Entrapped oil was documented extending at least 190 m southeast and 440 m northwest of the spill site. Molina (1994) observed that oil remained on the reef flat for at least three weeks after the spill in the form of sunken oily debris and oil entrapped in the reef matrix, coral rubble, and associated sediments. Oil persisted in the sediment at the grounding site for at least 22 months after the spill (D. Palawski, USFWS, unpubl. data). Diesel fuel also was detected in sediment samples taken from the lagoon terrace and lagoon slope, indicating that reef organisms were exposed to petroleum hydrocarbons for an extended period of time.

Response Actions

Initial response actions included: 1) estimating the amount of fuel discharged; 2) limited documentation of marine life mortalities; and 3) an initial attempt at salvaging the vessel. No fuel or lube oil was removed or recovered from either the vessel or the reef.

The vessel grounded in an area of high wave energy and broke up before a salvage tug could reach the atoll (Barclay 1993). When salvage operations began on November

27, 1993, the stern of the vessel (approximately 250 tons) was nearly submerged on the shallow reef slope with only a small amount of rigging above water. The bow section (76 tons), wheelhouse (5 tons), shelter deck (2 tons) and miscellaneous pieces of the ship (38 tons) were scattered over the reef flat, covering an area of approximately 9,000 m². Ship debris was also spread over an estimated 175,000 m² of reef flat and lagoon terrace, although the majority was concentrated in a 100-m wide band adjacent to the wreck (Barclay 1993).

Salvage operations removed most of the larger pieces of wreckage and debris from the reef flat. These operations included pulling the bow, wheelhouse, shelter deck, and miscellaneous pieces of ship wreckage off the reef flat into deeper water (600 to 1,000 m). The mass of the stern (approximately 160 tons) prevented its removal from the shallow reef slope (Barclay 1993). In the months following the salvage operation, high wave energy broke the stern into smaller pieces.

Recent surveys revealed that much of the wreckage is still present on the reef flat and reef slope, nearly six years after the salvage operation was terminated (J. Maragos in prep.). Funding for initial emergency restoration actions was provided by the USFWS, Pacific Islands Ecoregion, Refuges Division. Initial emergency restoration actions in July and August 1999 succeeded in the removal of 75 tons (about 99%) of the metallic debris from the reef flats, as well as approximately 2 tons of debris from the lagoon. Additional emergency restoration actions in April 2000 resulted in the removal of 30 tons of metallic debris and several tons of line and nets from the reef slope (Maragos 2000). The debris was transported to a U.S. Environmental Protection Agency-designated ocean disposal site located approximately 6 km north of the atoll. Approximately 40 tons of large metallic debris remain on the reef slope and 10 tons of non-metallic debris remain in the lagoon. Another 2 tons of metallic debris have washed up on the reef flat from the reef slope between August 1999 and April 2000. Removal of the remaining debris is expected to allow complete recovery of the atoll reef ecosystem.

Involvement of the Responsible Party

The owner of the F/V *Jin Shiang Fa* is Jin Ho Ocean Enterprise Co., Ltd., a Taiwanese business incorporated in 1985. Under the U.S. Oil Pollution Act and associated Natural Resource Damage Assessment regulations, this company was designated as the responsible party for the spill that injured the natural resources at Rose Atoll NWR. According to the law offices of LeGros, Buchanan and Paul, which represented the insurance interests of the responsible party, the company's sole source of income was the sale of fish from the vessel, and the vessel was the company's only asset. The company and the vessel had Protection and Indemnity insurance coverage through Shipowners' Mutual Protection and Indemnity Association (Luxembourg). Under the policy, the insurance company was only obligated to reimburse costs paid by the insured. The insurance company claims to have paid in excess of 1.1 million dollars for the salvage operation. It has also asserted that it has exceeded the vessel's limitation of liability, and has refused to pay for any further expenses. The United States

determined not to file an action to recover its response costs. Given these circumstances, there has been no participation by the responsible party in the assessment process.

Injury Determination

Chapter 3

3.1 Pre-Assessment Screen

Data was collected for a pre-assessment screen (PAS) in the weeks following the ship grounding. That data showed that oil sheens and oily debris were spread across the reef and lagoon and oil was entrapped within coral rubble and sediments. Additionally, biologists documented an extensive area where oil killed the reef-building pink crustose coralline algae (*Hydrolithon* or *Porolithon* spp.) as well as hundreds of marine snails, boring sea urchins (*Echinometra* spp.) and giant clams (*Tridacna maxima*). Opportunistic blue-green algae (the cyanobacteria *Lyngbya* and *Oscillatoria* spp.), which often invade a tropical reef after an oil spill, were also first noted at this time (USFWS 1996a).

A review of the evidence gathered during the PAS process allowed the Trustees to determine that:

- The Oil Pollution Act applies to the spill;
- Natural resources under the jurisdiction of the Trustees were injured by the spill;
- Response actions did not adequately address injuries to trust natural resources; and
- Feasible restoration actions exist to address injuries to trust natural resources.

On the basis of the above determinations, the Trustees began planning for restoration with the initiation of a natural resource damage assessment.

3.2 Natural Resource Damage Assessment

An ongoing natural resource damage assessment has confirmed that the reef ecosystem suffered substantial and extensive oil-related injuries (USFWS 1997). These injuries are summarized below.

3.2.1 Reef-building Corals

Prior to the spill, the living matrix that formed Rose Atoll NWR was composed primarily of crustose coralline algae. Observations during and after the oil spill indicated that the coralline algal community was severely impacted and significantly altered by the petroleum released during the grounding. The following oil-related injuries and changes were documented:

- A massive die-off of crustose coralline algae, extending approximately 1000 m along the reef flat and reef margin, occurred on the southwest arm of the atoll where the vessel grounded. Dead or injured coral also were documented along the outer reef slope and terrace, and the slope, floor and pinnacles of the lagoon (Maragos 1994, USFWS 1997).
- The large scale die-off of the crustose coralline algae was accompanied by a bloom of opportunistic invasive “weedy” species (cyanobacteria and the articulated coralline algae [*Jania* spp.]), which were previously uncommon on the atoll. Within a year, these 'weedy' species had spread across the atoll's entire southwest arm and had begun to invade adjacent areas of the lagoon as well as portions of the northwest arm (USFWS 1997).
- By 1995, data showed that sampling stations previously dominated by crustose coralline algae were now almost entirely (up to 90%) covered by the opportunistic invasive 'weedy' species (USFWS 1997).

3.2.2 Sea Urchins

- Early observations indicated that many boring sea urchins were killed by the oil spill, mostly along the outer reef flat (USFWS 1997).
- Surveys in 1993 revealed that boring sea urchins were extirpated from a zone 90 m north and 60 m south of the spill site. Surveys conducted in 1995 and 1996 revealed that sea urchin densities had declined along the atoll's entire southwest arm (USFWS 1997).

3.2.3 Sea Cucumbers

- The abundance of sea cucumbers (*Holothuria* spp.) was reduced in the vicinity of the grounding site immediately following the spill (USFWS 1997).
- Surveys in 1995 and 1996 revealed that the southwest arm of the atoll had the lowest density of sea cucumbers.

3.2.4 Giant Clams

- Initial surveys showed that a large number (>200) of giant clams died in the immediate vicinity of the spill. Dead clams were recorded along the reef flat and lagoon terrace up to a distance of 400 m from the grounding site (USFWS 1997).
- Surveys conducted six months after the spill revealed that clams on the lagoon terrace and pinnacles adjacent to the wreck site were covered with a thick growth of cyanobacteria. These clams appeared physiologically stressed, as evidenced by abnormally heavy mucus production (USFWS 1997).
- Clam mortality remained elevated at the spill sited in 1994 and 1995, indicating that oil-related effects were still apparent 12 to 18 months after the spill (USFWS 1997).

3.2.5 Fishes

- The cyanobacteria bloom produced by the oil spill altered the fish community in the vicinity of the grounding site. Herbivorous species, such as surgeonfish (*Acanthurus triostegus*) and parrotfish (*Scarus frontalis*), increased in abundance, while those species associated with a healthy reef ecosystem such as butterflyfish (*Chaetodon* spp.) and damselfish (*Chromis acares*) decreased in abundance (USFWS 1997).
- Alterations in the fish community were still evident two years after the spill, and appeared to be maintained by the on-going cyanobacteria bloom and altered physical habitat (USFWS 1997).

3.3 Recent Field Surveys and Natural Recovery

Recent field studies revealed that the reef ecosystem remains severely altered both intertidally on the reef flats and subtidally along the ocean and lagoon-facing reef slopes (Burgett 1998, J. Maragos in prep.) Limited natural recovery has occurred in areas where restoration activities have been implemented (J. Maragos in prep.). The following oil-related injuries were still apparent five to seven years after the spill:

- During 1997 surveys, cyanobacteria and articulated coralline algae dominated more than 800 m of the reef flat. Much of the normally abundant crustose coralline algae remains dead within this area, and shows no signs of recovery. By 1999, over 700 m of reef was still covered by the cyanobacteria and articulated coralline algae immediately prior to the initial reef flat cleanup. Upon completion of the initial cleanup, the area covered by these

species declined to approximately 400 m due to natural recovery in the areas where the cleanup occurred.

- The area of proliferating invasive species and dead crustose coralline algae has continued to **expand** and now includes portions of the atoll's northwest arm and lagoon.
- In 1997, several pinnacles within the lagoon were largely devoid of any living coral colonies and were dominated by large mats of cyanobacteria. Several pinnacles continue to be devoid of any living coral colonies as of April 2000.
- The sea urchin population continued to be reduced within 1000 m of the grounding site as of 1997.
- Sea cucumbers remain absent near the grounding site.

Detailed investigations of fish and giant clam populations were not conducted in 1998 due to time and funding constraints. Photoquadrat surveys of corals and clams were completed in 1999 at seven lagoon sites, but the data have not been analyzed. However, since neither the crustose coralline, sea urchin, or sea cucumber populations have recovered, and cyanobacteria and articulated coralline algae still dominate much of the reef area injured by the oil spill, there is no reason to assume the fish or giant clam populations have recovered from the effects of the oil.

In mid-1999, the zone of opportunistic invasive species still dominated most of the reef flats along the southwest arm of the atoll, but there were some signs that the area of coverage had shrunk in size as a result of the removal of some of the vessel debris in that area. Nevertheless the 'weedy' species still dominate the reef flat near the grounding site (J. Maragos, in prep.). The Trustees believe the data clearly shows that natural recovery will not occur for many years, if at all, thereby necessitating the continuation of active restoration efforts.

3.4 Conclusions

The pristine nature of Rose Atoll NWR was seriously impacted in October 1993 when the Taiwanese fishing vessel *Jin Shiang Fa* ran aground on the southwestern side of the atoll and spilled over 100,000 gallons of fuel and lube oil. Initial documented injuries due to the oil release included a massive die-off of crustose coralline algae, giant clams, boring sea urchins and other invertebrates in the vicinity of the spill site. Areas along the reef flat and reef slope where the coralline algae died were quickly colonized by opportunistic invasive species (primarily cyanobacteria and the articulated coralline algae). Conditions on the atoll over six years after the spill either show little improvement or have deteriorated. The crustose coralline algae have only shown limited recovery in areas where restoration activities have occurred and the 'weedy'

invasive bloom has expanded into other areas of the reef and lagoon. Sea urchins and sea cucumber numbers near the spill zone remain depressed. Although giant clams appear to be slowly recolonizing the impacted area, clams within the lagoon continue to show signs of physiologic stress.

The die-off of crustose coralline algae is of particular concern for the future management of Rose Atoll NWR, since this algae is the primary reef-building plant on the atoll. In the absence of a healthy crustose coralline algal community, reef growth may fail to keep pace with storm erosion or rising sea levels. The structure of the reef also may become weakened in areas where crustose coralline algae are absent. Either scenario could lead to unpredictable changes in the water circulation patterns across the atoll, or possibly result in a breach of the southwest arm of the atoll. Such an event would produce catastrophic changes in the lagoon's protected ecosystem, and would threaten critical nesting habitat for federally protected seabirds and sea turtles.

The bloom and expansion of opportunistic invasive species at the spill site is also of major concern. Although such blooms are common after an oil spill in the marine environment (Bellamy *et al.* 1967, Houghton *et al.* 1991, Jackson *et al.* 1989), they are usually ephemeral, lasting only several months to a year (Bellamy *et al.* 1967, Keller and Jackson 1993). The bloom at Rose Atoll is now in its sixth year, it has expanded, and it is most persistent in areas containing high levels of dissolved iron associated with vessel debris. Iron has been shown to be a limiting nutrient for algae in oceanic environments (Martin and Fitzwater 1988), and it seems likely that the algal bloom at Rose Atoll is being maintained or enhanced by the presence of this element above baseline levels. Initial emergency restoration activities begun in 1999 corroborate these data and evidence.

The Trustees injury assessment data indicates that immediate action is necessary to address conditions that are preventing the resources injured by the oil spill from returning to their baseline condition. The remaining vessel debris must be removed before the reef will be able to fully recover from the adverse effects of the *Jin Shiang Fa* oil spill. The Trustees data also suggests that without intervention, this once pristine atoll will not only continue to degrade, but could undergo a catastrophic change if crustose coralline algae populations do not return to their pre-spill abundance and distribution. It is therefore necessary to complete restoration actions at Rose Atoll as soon as possible.