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**Status of Nearshore Sports and Commercial Fishing and Impacts on  
Biodiversity in the Tropical Insular Pacific**

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## Introduction

Fishing is one of the oldest human activities with direct impacts on marine biodiversity. Foremost among these is overexploitation, but fishing may also alter habitats, introduce alien species, and create pollution (Norse 1993). Fishing may indirectly threaten biodiversity by affecting predators, prey, and other organisms whose life histories are connected with fishery species or that influence the quantity or distribution of the habitats they occupy. Fishing can also be an additive stress to biodiversity already threatened by other agents (Sebens 1994; Hughes 1994).

Fisheries are one of the many threats to biodiversity that are linked to human population growth (Wilson 1992; Sachs 1994; Hughes 1994). Contemporary assessments of global commercial fisheries suggest that worldwide yields have asymptoted since 1990 despite increasing fishing effort. This increased effort without increased yield has coincided with the overexploitation of many historically large fisheries (FAO 1993; Platt 1994). Nearshore fisheries may be most susceptible to overexploitation because they are concentrated within narrow areas close to human population centers. Nearshore habitats of oceanic islands in the tropical Pacific may be among the most sensitive to human activities because small perimeter-to-area ratios and growing populations (Malcolm 1994) predispose their valuable but narrow coastal strips to overdevelopment and resource depletion.

Adverse impacts of commercial fishing on biodiversity are well documented in industrialized nations, as are lesser impacts of sports fishing (Sissenwine and Cohen 1991; Witman and Sebens 1992; Parsons 1992; Upton 1992; Norse 1993; Jamieson 1993). Much less has been published about impacts of commercial and sports fishing in the oceanic islands of the Pacific.

In this paper we first review the status of sports and commercial fishing in the tropical insular Pacific. Because international fisheries statistics variously combine insular

Pacific and continental landings (FAO 1993), it is difficult to identify fisheries trends throughout the Pacific islands. Thus we focus on Hawai'i, Guam, and American Samoa as areas with the best-documented fisheries data. We next evaluate the impacts that sports and commercial fishing have or likely will have on the region's biodiversity. We consider both direct impacts on habitat and resources from overexploitation and indirect impacts on species and habitat caused by the overfishing of species having key ecological roles. We conclude with a review and evaluation of fisheries management measures in the region and suggest changes needed for the conservation of biodiversity.

#### **Status of Nearshore Sports and Commercial Fishing**

Historically, harvest of nearshore resources in tropical Pacific Islands was largely for subsistence, and in many, particularly remote, Pacific Islands this remains unchanged. However, in islands with more developed economies such as Hawai'i, Guam, American Samoa, and some of the Fiji Islands, sports and commercial fishing are developed. Subsistence, sports, and commercial fishing may be distinguished by their goals: in subsistence fishing the objective is to obtain food, in sports fishing it is recreation, and in commercial fishing it is cash income. Fishing methods or gears usually differ, with commercial fishing using more advanced or more efficient gears. The term "artisanal" is often used to describe fishing based on traditional methods and gears, independent of whether or not it is subsistence or commercial. Sports fishing may refer to either light tackle harvest of nearshore fishes, or to offshore fishing for tunas and billfishes. Sports fishing is difficult to distinguish from commercial fishing in the tropical Pacific, because both target virtually the same species and at least some of the sports catch is often sold. The harvest of reef organisms for the aquarium trade is included in commercial fishing because it produces substantial income for several Pacific islands (Pyle 1993).

In Hawai'i, sports and commercial fisheries harvest a diverse group of resources (Smith 1993). Forty-seven species represent 91% (by weight) of the commercial landings taken between the shoreline and 200 m depth contour. Coastal pelagics, principally akule (Selar crumenophthalmus) and opelu (Decapterus macarellus), account for much of the landings while reef fishes, although of high economic value, represent only a minor portion. The most frequently used fishing gears inshore are handlines, trolling, diving, and gill and seine nets. Bottom trawls are not used due to the lack of flat, low relief habitat with commercially valuable species. There were over 200 aquarium collectors reporting 1988 harvests of 250,000 reef organisms, of which about half were collected from the Kona coast of the Island of Hawai'i (Smith 1993). Estimated annual landings for the State of Hawai'i from the shoreline out to 3 nmi is about 700 tons; an estimate of catch per area for the entire nearshore area (0-20 nmi) is about 65 kg/sq.nmi. Inshore catches have not shown any significant trend over the past decade, but nearshore effort has declined slightly--perhaps fishing has shifted farther offshore (Smith 1993). A prior evaluation (Shomura 1987) and a recent visual assessment of shallow reef fishes (Grigg 1994a) suggest that stocks have remained depressed for some time in the main Hawaiian islands.

In American Samoa commercial and recreational fisheries target pelagics and bottomfishes beyond the nearshore scope of this paper (Craig et. al. 1993). The shoreline fishery in American Samoa is primarily subsistence with some catch sold; in 1991 an estimated 200 tons valued at about \$800,000 was caught. The gears used are rod and reel, handline, free diving, gill net, and gleaning. About half the catch is bigeye scad (S. crumenophthalmus) and the rest are reef-associated organisms. The average size of most harvested reef fishes is relatively small and some favored species such as giant clams are scarce, indicating heavy nearshore fishing pressure.

In Guam the nearshore reef fishery harvests over 100 species of fishes and 40 other organisms (mostly mollusks) with hook and line, nets, spear, and gleaning methods (Hensley and Sherwood 1993). Seasonal harvests of juvenile fishes, primarily rabbitfish (Siganidae) and bigeye scad, can be significant in years of strong recruitment. Reef corals were once harvested but that is now illegal and the regulation strictly enforced. Use of explosives and poisons as harvest methods are also illegal and enforcement is reducing their use. During the past decade, fishing catch and effort in the nearshore, excluding erratic catches of juvenile rabbitfish and bigeye scad, have declined but fishing mortality may still be high for nearshore species.

These three examples describe multispecies and multigear nearshore commercial fisheries. Nearshore reef fisheries in most other Pacific Islands are subsistence, but nearshore commercial fishing for reef fishes will likely become more widespread as populations grow and economies change.

In some Pacific islands there are various nearshore commercial fisheries (Wright and Hill 1993) which target single species such as bech-de-mer, giant clams, trochus snail, pearl oysters, green snails, and seaweed (Preston 1993; Munro 1993; Nash 1993; Sims 1993; Yamaguchi 1993; South 1993). These resources occur in shallow nearshore and lagoon areas and are typically captured by free divers, divers with hookah gear, and occasionally with scuba gear. Historically fisheries for these resources have been erratic. Demand and price for these resources can fluctuate widely and stocks which are readily accessible in shallow water can be easily fished down.

It is likely that fundamental differences exist in the way in which single and multispecies fisheries affect biodiversity, depending on species and variations in the strengths of ecological interactions within communities. These differences are explored in the following review and discussion of fishery impacts.

### **Impacts on Biodiversity in the Tropical Insular Pacific**

Definition of diversity.--Four levels of biodiversity are generally recognized: (1) genetic diversity--the information encoded in the genes of individual organisms; (2) species diversity--the number and distribution of species in an area; (3) ecosystem diversity--the maintenance of ecosystem function; and (4) landscape diversity--the spatial heterogeneity of ecosystems within large regions (Cairns and Lackey 1992; Norse 1993). Loss of species diversity (global extinctions) initiated concern that the earth is in a biodiversity crisis (Wilson 1992), but ecosystem diversity should be the greatest present concern of resource management. Ecosystem function can be disrupted by marked changes in the relative abundances of certain species, as well as the loss or gain ("replacement") of species (e.g., Jones 1992; Longhurst and Pauly 1987; Hughes 1994). As ecosystems change they either function differently or cease to exist, with extinctions the eventual result. For this reason we define biodiversity in terms of relative abundance as well as species composition and presence-absence. Doing so has ample precedence in contemporary ecology, where organismal diversity is commonly measured as the numerical distribution of individuals among species ("evenness") as well as species richness (Magurran 1988).

Types of impacts.--Sports and commercial harvesting can have several related types of impacts on biodiversity. These include (1) direct impacts on the relative abundances or occurrences of harvested species; (2) indirect biological impacts (e.g., on predators or prey of the harvested species) that result from reduction or loss of harvested species; and both (3) direct and (4) indirect impacts resulting from habitat alteration or destruction. Habitat can be damaged directly by destructive fishing practices. Loss of habitat and associated diversity also can result from altering higher order interactions between habitat and exploited or other organisms whose activities regulate the amount or distribution of habitats in their

communities. All four types of fisheries impacts can occur on varying spatial scales that range from extremely local (e.g., a small fraction of one island's coastline) to regional (archipelago-wide) or greater. In general the larger the scale of reduction or loss, the greater the impact; of course, even local scales of extinction can be catastrophic for endemic species.

Evidence for and against each of these possible phenomena is reviewed for tropical Pacific islands in the following sections. Findings for the region are discussed relative to examples in other tropical and better-studied temperate ecosystems. We conclude this section with a regional synthesis of fishery impacts on biodiversity.

Direct Impacts on Fishery Resources.--The most straightforward type of potential impact of sports and commercial fishing is severe reduction or loss of harvested species. The most striking examples for the tropical insular Pacific are giant clams (Tridacna gigas, Hippopus hippopus), many of whose local populations in the Pacific islands have been decimated by international poaching (Munro 1989, 1993; Jamieson 1993 and references). Intensive single species fisheries for giant clam, bech-de-mer (Preston 1993), pearl oysters (Pinctada spp., Sims 1993), and coconut crab (Birgus latro; Fletcher 1993) may represent the only clear examples of the local loss of overharvested species in the region. None of these resources (except perhaps sea cucumbers) appear to have key ecological roles in their respective communities. There are no examples of fishery-caused extinctions at the species level in the tropical Pacific islands. However, other types of fisheries impacts on biodiversity exist or are likely.

Russ (1991) defined four types of overfishing: growth, recruitment, economic, and ecosystem. Growth overfishing and economic overfishing affect yields but do not threaten biodiversity. Recruitment overfishing, a sign of threatened

biodiversity, occurs when a population is exploited beyond the level at which reproduction can replace the numbers lost to a fishery. Recruitment overfishing has not been a concern for tropical regions in the past, although Hawai'i's deepwater demersal fisheries are now partly managed to avoid recruitment overfishing (Wright 1993). Ecosystem overfishing occurs when one species declines in abundance and another replaces it, resulting in changes in ecosystem function. Ecosystem overfishing is more likely in populous tropical areas than in more developed temperate nations for several, complementary reasons. The high diversity faunas of tropical coral reef ecosystems typically support multispecies fisheries that are easily accessed nearshore. Species with high "catchability" (fraction of population caught per unit of fishing effort) are especially vulnerable to extirpation--even after harvest of the species decreases below economic profitability--if they occur with (and continue to be exploited as a bycatch of) other species that remain economically valuable targets (Munro and Fakahau 1993a). Groupers (Serranidae) are a prime example.

Large-bodied, predatory (often piscivorous) fishes such as snappers and groupers are usually targeted in multispecies bottomfisheries and nearshore reef fisheries (Russ 1991). Numerous recent assessments of marine fishery reserves illustrate the results of targeting large predators. The study by Cole et al. (1990) in New Zealand is representative: the average body size of a predatory snapper was smaller outside of a reserve than within it, and there was a suggestion (insignificant because changes in abundance are more difficult to document than changes in body size) that snapper numbers and biomass were reduced outside. The results of overexploitation are even more extreme in Jamaica and Haiti, where fish over 30 cm long are nearly absent in areas where fishing is intense (Sebens 1994).

Indirect Biological Impacts.--Other community members such as the prey or predators of harvested species are at indirect risk due

to overharvesting of the species that influence their abundances. Most of the little existing evidence suggests that predator overexploitation more commonly impacts prey than vice versa. This is consistent with the top-down structuring of prey assemblages by predators that might be expected for predator-limited marine systems (Valiela 1984).

Much descriptive, but few experimental or other definitive, data exist on whether predators structure prey assemblages in coral reef or other nearshore ecosystems of the tropical insular Pacific. Parrish et al. (1985), Munro et al. (1987), and Norris and Parrish (1988) provided information consistent with predator structuring of prey assemblages in the tropics including Hawai'i. Schroeder (1989), working on lagoonal patch reefs at Midway Atoll in the northwestern Hawaiian Islands, presented experimental evidence which suggests that the magnitude of prey fish recruitment can be inversely proportional to the abundance of piscivorous fishes.

Numerous studies of predator effects on prey exist for coral reefs in other regions. Most indicate or suggest that certain predators at least contribute to the structuring of prey assemblages. Hixon (1991) recently reviewed most available literature and concluded that the evidence was either inconclusive or suggested that predatory reef fishes influence the composition, distribution and abundance of prey. At least one more recent study exists: Shpigel and Fishelson (1991) observed no changes in prey assemblage structure or the estimated abundances of prey species following removals of piscivorous Cephalopholis spp. groupers on reefs of the lower Gulf of Aqaba, Red Sea. The study tracked prey and predator responses for three years after the uncontrolled removal of groupers. Shpigel and Fishelson (1991) nevertheless were able to detect increases in the abundances of other species of piscivorous fishes in their removal areas; that these increases were consistent (123%, 143% and 175%) across all three study habitats suggests that the pattern was real.

The only other reasonably convincing example of a "keystone predator" influencing the abundances of other piscivorous reef fishes is Goeden's (1982) study of coral trout Plectropomus leopardus on Australia's Great Barrier Reef. Coral trout abundance was inversely proportional to distance from fishing ports and the abundance of other piscivores was inversely proportional to coral trout abundance (Goeden 1982), presumably due to competitive release.

Introduced fishery species.--Island species, endemics in particular, are especially susceptible to predation by, or competition with, introduced species (Paulay 1993). The introductions of predators or prey, whether accidental or purposeful, represent potentially serious threats to the diversity of resident species. Undoubtedly many such instances exist but have gone undocumented. A surprisingly successful and well-documented series of introductions, however, exist for the tropical insular Pacific. In the late fifties, about a dozen species of shallow-water epinepheline groupers and snappers (Lutjanidae) were purposely introduced from French Polynesia to Oahu and the island of Hawai'i (reviewed by Randall 1987a). Several snappers (toau, Lutjanus fulvus and especially taape, L. kasmira) and one grouper (roi, Cephalopholis argus) have become established and presently comprise minor parts of the nearshore reef fisheries in Hawai'i. Conclusive evidence is lacking both for and against impacts on resident species by any of these introduced species, including taape--the most "successful" species, which is publicly perceived as outcompeting resident fishes for food and habitat in Hawai'i (Oda and Parrish 1981).

One species of baitfish (the Marquesan sardine Sardinella marquesensis; Clupeidae) was purposely introduced to Hawai'i, but with little apparent success (Williams and Clarke 1983). Another case of a likely accidental introduction of a prey species is known (the gold spot herring Herklotsichthys quadrimaculatus; Williams and Clarke 1983; Randall 1987a). Apparently the latter

suddenly proliferated throughout nearshore Oahu in 1976, perhaps at the expense of a Hawaiian endemic, the iao Atherinomorus insularum (Atherinidae). Interestingly, even though iao and herring are both forage fishes, adult herring prey on larval-juvenile iao (Williams and Clarke 1983). It is not known whether the gold spot herring has had an impact on other resident species such as the nehu anchovy Encrasicholina purpurea (Engraulidae), another Hawaiian endemic.

Several tilapias have been introduced from Africa to Hawai'i and other tropical Pacific islands. Oreochromis mossambicus was purposely introduced to Hawai'i and elsewhere for aquatic weed control, food, and as a tuna baitfish (Nelson and Eldridge 1991). Sarotherodon melanotheron accidentally escaped from confinement in Hawai'i, where it was being evaluated as a tuna baitfish (Randall 1987a). These eurytopic mouth-brooders may be outcompeting pond-cultured milkfish Chanos chanos (Nelson and Eldridge 1991) and wild mullet (Randall 1987a).

Two other fishes (the mullet Valamugil engeli and the goatfish Upeneus vittatus) were inadvertently introduced to Hawai'i with the Marquesan sardine. The former may be displacing native mullet Mugil cephalus in some estuaries and aquaculture operations (Eldridge 1987b). Ecological effects of the introduced goatfish are unknown (Randall 1987a).

A number of purposeful introductions of commercially important shellfish are well-documented for the insular Pacific, including mangrove crab (Scylla serrata; Portunidae) from Samoa to Hawai'i; oysters (Crassostrea spp.) from San Francisco to Hawai'i; trochus snail within and between islands of Micronesia and Polynesia (Eldridge 1987b); and littleneck clams (Tapes japonicum) from Japan to Hawai'i (Yap 1977). Ecological impacts are unknown for any of these introductions. None are likely ecological dominants. The dearth of protected estuarine embayments has probably limited the spread of potentially important oyster reef habitat in Hawai'i.

Direct Impacts on Habitat.--Fisheries impact habitats to extents that vary greatly depending on whether methods are passive or active (in the latter, fishing gear is brought to the resource rather than vice versa; Alcala and Gomez 1987). Several active techniques--bottom trawling (Sainsbury 1987), dynamite "blast fishing" (Alcala and Gomez 1987), and "muro-ami" and "kayakas" (Gomez et al. 1987) have and continue to be used in other tropical regions. Tangle-mop dredging for deep-water (400 m) precious corals in Hawai'i (Grigg 1994b); blast fishing in Guam and elsewhere in Micronesia (Alcala and Gomez 1987); and the use of poisons in Ponape, Palau, Western Samoa, and the Mariana and Marshall Islands (Eldridge 1987a) were formerly significant. All are clear examples of fishery practices that result in major habitat destruction, but most are not presently used to great extent in the tropical insular Pacific. Damage to reef corals caused by harvesting attached reef invertebrates for the aquarium trade (Randall 1987b) might be an existing problem. The collection of feather duster worms (Polychaeta, Sabellidae) in the Hawaiian aquarium trade may be a significantly destructive fishing practice, but data on its prevalence and effects are lacking (Everson 1994).

Indirect Impacts on Habitat.--Biotic diversity also can be impacted by the overharvesting of organisms that provide habitat (e.g., corals and seaweeds) or organisms that influence the amount and distribution of habitat structure (e.g., urchins that limit plant biomass and contribute greatly to the bioerosion of reefs). Prior unregulated collecting of reef corals and shells in Guam hopefully is over. The overfishing of other habitat-formers such as seaweeds (South 1993) does not presently appear to be a problem in the tropical insular Pacific. A potentially serious problem exists in Fiji, however, where urchin fisheries may overdevelop in the future.

Many examples of the effects of overharvesting exist for urchin fisheries, mostly in temperate seas (references in Witman

and Sebens 1992). A clear example exists for coral reef ecosystems in Kenya, Africa (McClanahan 1992, 1994, and references; Watson and Ormond 1994). Coevolved communities of benthic algae, omnivorous urchins, herbivorous fishes, and urchin predators (triggerfishes, Balistidae; emperors, Lethrinidae) characterize the lagoonal and fringing coral reefs of Kenya. Predatory fishes support important subsistence fisheries, and it has been necessary to establish harvest refugia to conserve fish stocks. Triggerfishes naturally control urchin abundances on lagoonal reefs, and urchins proliferate where triggerfishes are overexploited outside of no-harvest zones. The diversity of coral reef fish assemblages is generally greater inside versus outside harvest refugia, presumably because urchins destroy and modify reef fish habitat (McClanahan 1994). Hughes (1994) described another dramatic example of the indirect effects of fisheries on urchins, algae, and reef corals in Jamaica.

A striking example of an indirect effect of fishing on a keystone predator, analogous to urchin-algae interactions, may exist for the insular tropical Pacific. The removal of certain predators of crown-of-thorns starfish (e.g., triton's trumpet shell, Charonia tritonis) may have contributed to the epidemics of this starfish that have aperiodically denuded coral reefs throughout the Pacific (Birkeland and Lucas 1990, cited in Sebens 1994).

Regional synthesis and conclusions.--A few intensive single species fisheries in the tropical insular Pacific (e.g., giant clam, bech-de-mer, pearl oyster) have clearly resulted in depletion and local extirpation of the harvested species. With these few exceptions, though, existing data do not demonstrate beyond reasonable doubt that the known or likely overharvesting of a species has resulted in a loss of biodiversity throughout the region. Intensive single species fisheries like that for giant clam have and will continue to be the most likely causes of locally reduced species diversity.

Cases of ecosystem overfishing akin to those in Haiti and Jamaica (Sebens 1994; Hughes 1994) are presently unknown in the tropical insular Pacific. However, we view the direct and indirect impacts of ecosystem overfishing as representing the most serious potential threats to ecosystem diversity in the region. Overdeveloped multispecies fisheries represent more insidious and wide-ranging threats because ecosystem function can be impacted as indirect effects ramify within feeding guilds and between trophic levels. Existing data suggest that the indirect biological effects most likely to result from the overharvesting of piscivorous predators are changes in predator assemblages. Many undocumented cases of man-induced changes in predator assemblages likely exist; the present general lack of evidence probably reflects the difficulty of detecting changes in abundances of large, rare species. Clearly, data are needed on the ecological significance of changing the composition and relative abundances of species within nearshore prey and predator assemblages.

Although the purposeful introduction of exotic species is no longer standard policy and is at least nominally prohibited most places in the tropical insular Pacific, the accidental introduction of exotics, particularly piscivores (inadvertent "predator addition" experiments), continues to pose real threats to biodiversity in the region. Continuing, purposeful "translocations" of habitat-formers like the red alga Euclima (South 1993) also are potentially significant problems.

Habitat alteration and loss through fishing practices represent threats of secondary importance, because habitat-destructive fishing practices are prohibited and regulations are generally obeyed as the negative impacts of failing to do so are readily apparent to the public. Habitat destruction otherwise represents the most serious threat to nearshore biodiversity in the tropical insular Pacific (\_\_\_\_\_, this volume).

### **Management of Sports and Commercial Fishing**

In Hawai'i regulatory measures for inshore fisheries are species and area specific and include catch limits, seasonal closures, minimum size, gear restrictions, and several relatively small marine parks closed to all fishing (Smith 1993). While the focus of most regulations is to protect the resources from overfishing, some (such as gear restrictions) are designed to minimize conflicts between users, e.g., between net fishermen and pole and line fishermen. Shallow-reef reserves are currently in use on the Kona coast of Hawai'i to reduce conflicts between aquarium fish collectors and dive tour operators (Pyle 1993). In Guam seasonal, area, gear, and size regulations are used but these generally apply only to nonfinfish resources such as lobster, giant clams, trochus, and crabs (Hensley and Sherwood 1993). The main regulation applying to finfish is a gill net minimum mesh size of 1.5 inches. Guam has also developed regulations currently awaiting approval for marine conservation areas to provide refuges closed to all fishing (Hensley and Sherwood 1993). Few if any management regulations are applied to harvests of beche-de-mer, giant clams, trochus, or pearl oysters, although minimum size, closed areas, and catch quotas have been proposed. Fishery management measures and their enforcement in American Samoa are presently developing (Craig et al. 1993).

Current fisheries management throughout much of the tropical insular Pacific is rudimentary if it exists, despite long histories of successful use of tenure systems by native cultures. Traditional Eurocentric management practices have developed along with cash economies and increased resource exploitation. Hawai'i and Guam, as the two most populous and developed cases, are partial exceptions in that some form of harvest refugia--the state-of-the-art in fisheries management (Roberts and Polunin 1991; Bohnsack 1993)--are in use or being considered for use. Reserves may be especially appropriate for reef systems (Huntsman 1994).

The long-term future of resource management in the developing island nations lies in community-based limited or exclusive entry, not common access, systems (Munro and Fakahau 1993b). The development and implementation of management systems with close ties to traditional island cultures is key (Munro and Fakahau 1993b; Johannes 1994; Ruddle 1994). Unless there is ownership to assure long-term personal interest and commitment to maintaining sustainability, compatibly implemented within island cultures, resources will be overharvested as part of the inevitable process of overdevelopment.

### **Remedial Actions**

Three basic classes of remedial actions exist that can potentially be used to restore fishery resources and the associated biodiversity of their ecosystems. These are (1) hatchery production for fishery enhancement or stock recovery, (2) habitat restoration, and (3) the promulgation of reduced-entry fisheries based on traditional ocean tenure systems. These options differ in degree of difficulty to develop and implement and in related economic and social costs and benefits. A discussion of each follows.

Hatchery production.--Development of techniques to culture and mass-produce resources can be used in the short-term to augment fisheries take and in the long-term to bolster stocks. The inadvertent introduction of other organisms (e.g., parasites) must be avoided in either case. Stock augmentation of course has greater merit, but is further complicated by the problem of maintaining sufficient levels of natural genetic variability. Excellent examples in the tropical insular Pacific include the rearing of mahimahi (Coryphaena hippurus) by the Hawai'i State Department of Natural Resources and mullet (Mugil cephalus, Mugilidae) by the Oceanic Institute in Hawai'i; and giant clam by the Micronesian Mariculture Development Center in Palau. Recent breakthroughs have occurred in the mass-culturing of some

aquarium fishes (Danilowicz and Brown 1992) and reef corals for the aquarium trade that have the added potential for reseeding depleted reefs (Yates and Carlson 1993). A significant danger of hatchery production is that it can become a new source of fishery introductions unless the distribution of hatchery-produced species is limited to areas where they are indigenous.

Habitat restoration.--The augmentation or re-establishment of reduced or destroyed habitats is an important option for remedying non-fishing impacts of biodiversity on tropical Pacific islands (\_\_\_\_\_, present volume). However, because current fishing techniques in the region generally do not destroy habitat, the need to restore habitat lost through fishing activities is limited. Damage to coral reef, mangrove, and seagrass habitats in some developing Pacific island states has been significant (e.g., in Guam), but the current cause is environmentally insensitive urbanization and resulting sedimentation, not fishing practices.

Ocean tenure management.--Perhaps the most difficult to implement, but generally beneficial and long-term management option, is the development and implementation of ocean tenure-based systems whereby a limited number of owners regulate the harvest of resources based on traditional cultural practices. Fishery reserve systems need to be implemented within the cultures of local societies. The use of fishery reserves to promote conservation consciousness as well as ecotourism should be developed with the support of effectively managed international development grants. Educating general populaces in the importance of marine stewardship and the self-regulation of harvests holds the best promise for sustainable resource exploitation and the conservation of biodiversity in nearshore waters of the tropical Pacific islands.

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