THE LIVE REEF FISHERIES OF PALAU

HISTORY AND PROSPECTS FOR MANAGEMENT

DECEMBER 2001

The Nature Conservancy
Saving the Last Great Places

USAID

Published by: The Nature Conservancy, Asia Pacific Coastal Marine Program

Produced by: Tom Graham, PO Box 235, Honolulu, HI 96809; thomasrgraham@aol.com under TNC contract APRO/GRAH011300. Final report submitted October 2000.

Citation: Graham, T. 2001. *The Live Reef Fisheries of Palau: History and Prospects for Management, December, 2001*. Asia Pacific Coastal Marine Program Report # 0103, The Nature Conservancy, Honolulu, Hawaii, U.S.A: 85 pp.

This publication was made possible through support provided by The David and Lucile Packard Foundation. Additional support was provided by the Office of Environment and Natural Resources, Bureau of Global Programs, Field Support, and Research, U.S. Agency for International Development, under the terms of Award No. LAG-A-00-99-00045-00. The opinions expressed herein are those of the author(s) and do not necessarily reflect the views of the U.S. Agency for International Development.

Cover design: Hirasaki Nakagawa Design

Text Editing: Susan Arritt

Available from: The Nature Conservancy
Asia Pacific Region
Coastal Marine Program
923 Nu'uanu Avenue
Honolulu, HI 96817

Or via the worldwide web at: www.conserveonline.org

THE LIVE REEF FISHERIES OF PALAU

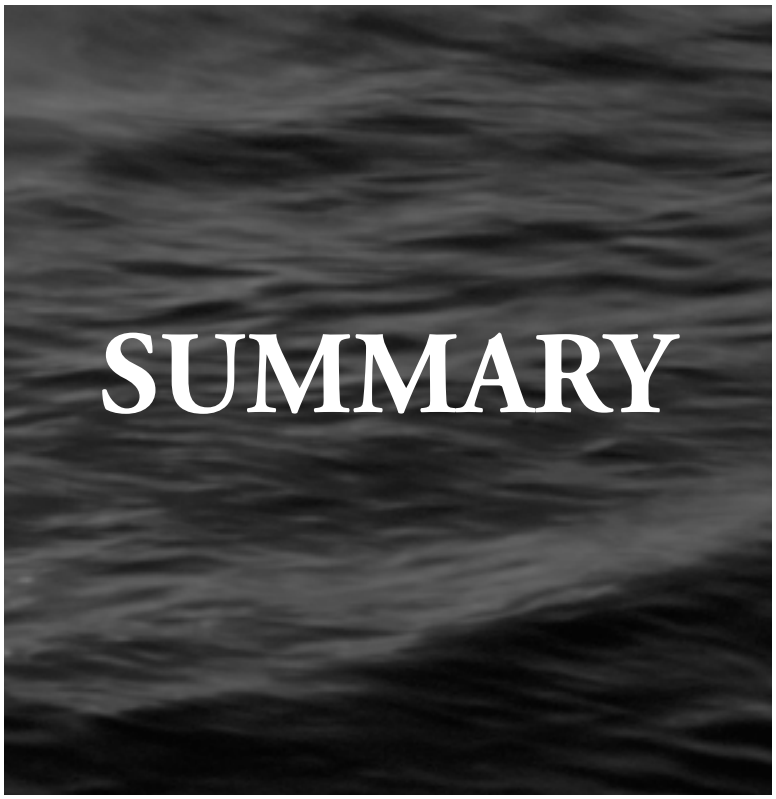
HISTORY AND PROSPECTS FOR MANAGEMENT

Thomas Graham

DECEMBER 2001

TABLE OF CONTENTS

TABLES AND FIGURES


SUMMARY

1. SUMMARY

1.1 HISTORY OF THE FISHERY

Ornamentals

Palau's first exports of live ornamental reef products were probably in the late 1980s, but the first well-established operation started in 1990. That company operated for about four years, and at its peak in 1992 exported roughly 200,000 pieces of finfish and 20,000 pieces of invertebrates per year. The company changed hands in 1994 and operated for another two years, exporting roughly 100,000 pieces of finfish and 40,000 pieces of invertebrates per year. A new company established itself in late 1998, and after a year of focusing on invertebrates, gradually shifted to finfish. In 2000 the company exported about 60,000 pieces of finfish and 10,000 pieces of invertebrates.

All the companies were at least nominally Palauan-owned and employed both local and foreign collectors and other workers. The United States was the main market. Among exported finfish, Pomacentridae was the dominant family in terms of both numbers and revenue, and *Chrysiptera cyanea*-the male of which has distinctive color markings in Palau-strongly dominated finfish sales for all three companies. Important invertebrates included tridacnid clams (grown at the government's Palau Mariculture Demonstration Center), particularly *Tridacna derasa*, the blue starfish, *Linckia laevigata*, and various soft corals, urchins, snails, and crabs.

In summary, as of the end of 2000, a total of three companies had operated in Palau, mostly in fishing grounds close to the urban center of Koror but also in waters around the island of Babeldaob. The companies exported a total of roughly 800,000 pieces of live ornamental finfish and invertebrates over a period of 11 years. As of the end of 2000 one operation was active and apparently growing. At an export rate of 100,000 finfish per year, as occurred in the early 1990s, Palau's exports contributed roughly 6 percent of the Pacific Islands' production of marine ornamental finfish and 0.5 percent of total global production. Palau's relative contribution in terms of invertebrates is less clear, but it has clearly been an important producer of tridacnid clams, soft corals, and certain other invertebrates, and until their export was severely restricted in 1994, probably of live rock and sand, as well.

Food Fish

Palau started exporting live reef fish products in the mid 1980s with the establishment of a live reef food fish operation in the southern lagoon near the urban center of Koror. That operation produced and exported about 75 mt of live reef food fish by sea over the course of about five years. Shortly after that operation stopped, a second company started operations at remote Helen Reef. That enterprise lasted about two years and exported roughly 50 mt of live product by sea. After about two years of no activity a new joint venture started fishing at Helen Reef in 1993, operating for almost three years and exporting about 40 mt by sea. In the meantime, the northern reefs of the main archipelago started being fished in 1994 by an enterprise that exported by air rather than by sea. That operation lasted about three years and exported about 12 mt. After the end of that operation in 1996 there has been no activity except for a short-lived operation in the northern reefs in 1999 that exported about 2 mt by sea.

All the enterprises were foreign-local partnerships to at least some degree. The level of local involvement in the companies tended to increase over time, as did the degree of local control over, and participation in, fishing operations. Hong Kong was the destination for virtually all exports. It appears that the dominant species exported were *Epinephelus polyphekadion, Plectropomus areolatus,* and *P. leopardus*.

In summary, as of the end of 2000, a total of five operations had fished in three main fishing grounds and exported roughly 180 mt of live reef food fish over a period of 17 years. No operations were active as of the end of 2000. At the industry's peak in 1994-1995, Palau's export rate of about 25 mt per year contributed roughly 0.1 percent of the total regional trade to Hong Kong.

1.2 CURRENT MANAGEMENT

Palau's live reef fisheries are governed by state, national, and international laws. Key elements of the applicable laws follow:

Ornamentals

Permits

- Any person collecting more than five pieces of "aquarium species" in a single day must be the *holder* of an *Aquarium Collecting Permit*. Permits fees are $100 per year.
- Any person exporting from Palau any "aquarium species" must be the *owner* of an *Aquarium Collecting Permit*.
- Each permit is issued in the names of both a permit *holder* and a permit *owner*.
- "Aquarium species" are those species of finfish and invertebrates designated as such on the *Regulated Marine Species Register* maintained by the Division of Marine Resources.
- *Aquarium Collecting Permits* are not transferable among *owners* but they are transferable among *holders*.
- No more than 20 *Aquarium Collecting Permits* will be issued in any given year, and permit applications will be evaluated based on a set of criteria that include previous experience in the business, compliance with relevant laws, and contributions to marine life conservation efforts.
- An *Aquarium Collecting Permit* is valid only when endorsed by the proper authority of the state in which aquarium species are being collected.
- Some states require permits for certain types of fishing.

Investment and participation

- Ownership of businesses that engage in fishing for other than highly migratory species is reserved exclusively for Palauans.
- Only Palauan citizens are eligible to obtain *Aquarium Collecting Permits* as permit *holders* (i.e., collectors); there are no such restrictions on permit *owners.*

Species

- Hard corals (including "live rock") and sponges may not be exported, but exemptions are provided for cultured specimens, specimens collected from permitted dredge sites, and specimens collected for permitted research purposes.
- The export of any species of tridacnid clam, except cultured ones, is prohibited.
- The national government may at any time further restrict the collection or export for aquarium purposes of any species of marine organism, such as through a ban or a daily or annual bag limit or quota.

Methods

- There are only three types of fishing gear that may be used to collect aquarium species: barrier nets, drop nets, and hand nets.
- The use of explosives or poisons for fishing is prohibited.
- The use of compressed air while fishing, except as provided by regulation or permit issued by the Minister of Resources and Development, is prohibited.
- Some states have restrictions on certain fishing methods, including Koror State, which prohibits the use of explosives, poisons, compressed air, and nets with mesh sizes of less than 3 inches on any side of the hole.

Areas

- Fishing from April through July is prohibited at and fishing any time is prohibited in the Ngerukewid Islands Wildlife Preserve.
- Some states restrict fishing in certain areas, including Koror State, which prohibits fishing in the areas of Soft Coral Arch, Cemetery Reef, Ngkisaol, any marine lake, Ngerukewid, Ngerumekaol, and within one mile of the shores of Ngemelis and Dmasch islands.

Inspections and Reporting

- All exports of aquarium species are to be inspected by the national government.
- Owners of *Aquarium Collecting Permits* must report their catches and exports.
- Exports of any marine products must be declared in writing prior to export, including the net weight exported for each species and the product form (e.g., live or dead). Containers that hold marine products are to be labeled as such. Commercial exporters must submit quarterly catch and effort reports to the Division of Marine Resources.

Trade

- The export of species listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to countries party to the convention must comply with those countries' applications of the convention. Products affected include tridacnid clams and stony corals, which are listed on Appendix II of the treaty, meaning that trade is allowed but export documentation and compliance with applicable laws of the exporting country are required. Live rock, sand, and soft corals are also affected if composed of or attached to listed species.
- The Lacey Act of the U.S. prohibits the import of fish or wildlife taken, possessed, transported, or sold in violation of any foreign law.

Food Fish

Permits

- Some states require permits for certain types of fishing, including Koror State.

Investment and Participation

- Ownership of businesses that engage in fishing for other than highly migratory species is reserved exclusively for Palauans.
- Fishing for reef fish may not be done by foreign vessels.

Species

- Fishing for, buying, or selling any of five species of grouper, *Epinephelus fuscoguttatus, E. polyphekadion, Plectropomus areolatus, P. laevis*, and *P. leopardus*, from April through July is prohibited.
- The export of Napoleon wrasse, *Cheilinus undulatus*, is prohibited, as is fishing for, buying, or selling individuals that are less than 25 inches in length.

Methods

- The use of compressed air while fishing, except as provided by regulation or permit issued by the Minister of Resources and Development, is prohibited.
- The use of explosives or poisons for fishing is prohibited.
- Some states have restrictions on certain fishing methods, including Koror State, which prohibits the use of explosives, poisons, compressed air, and nets with mesh sizes of less than 3 inches on any side of the hole.

Areas

- Fishing from April through July is prohibited at Ngerumekaol (and fishing any time is prohibited in the Ngerukewid Islands Wildlife Preserve.
- Koror State prohibits fishing year-round in the areas of Soft Coral Arch, Cemetery Reef, Ngkisaol, any marine lake, Ngerukewid, Ngerumekaol, and within one mile of the shores of Ngemelis and Dmasch islands.
- Ngarchelong State prohibits entry and fishing year-round, at least until 2003, in an area surrounding Ebiil channel, an important spawning aggregation site for groupers and Napoleon wrasse.
- Kayangel State prohibits fishing at Ngeruangel atoll, with some exceptions.
- Ngeremlengui prohibits fishing year-round in two areas, Usas and Mecherong, and from June 1 to August 31 prohibits fishing in the channel Tewachel Mlengui, a known aggregation area for groupers.
- A traditional *bul* declared by the chiefs of Ngarchelong and Kayangel in 1994 prohibits fishing from April through July in all eight major channels in the northern reef complex (Ngkesol, Ngebard, and Ngarael), at least two of which, Ebiil and Western Entrance, are known to be important spawning sites for groupers.

Inspections and reporting:

- Exports of any marine products must be declared in writing prior to export, including the net weight exported for each species and the product form (e.g., live or dead). Containers that hold marine products are to be labeled as such. Commercial exporters must submit quarterly catch and effort reports to the Division of Marine Resources.

Trade

- There are no relevant restrictions on international trade for the important species and markets.

1.3 VIABILITY

Ornamentals

There appears to be no practical limit on the demand for the types of ornamental products that Palau can provide. The current level of harvest appears to be well within what the resource can sustainably produce, although better monitoring of impacts to particular species would be justified. Collecting activities undoubtedly cause some incidental physical damage to the benthos but the magnitude of those impacts is probably small compared to other sources. The problems stemming from the use of poisons that are prevalent in other source countries are not present in Palau.

The most important constraints on the industry appear to be the cost of freight (which is high compared to all other sources), the availability of cargo space (which competes with the sashimi tuna industry), and the costs of most inputs to production (which are high compared to Asian sources). Still, the current operation appears to be viable, in part through Palau's comparative advantage with certain species and the reputation of its product as being hand-caught.

Food Fish

The rapid growth of the regional live reef food fish trade in the last 30 years suggests that it has been a profitable industry, at least for some of its participants. But the fact that fishing operations have continually moved from one fishing ground to another suggests that the industry lacks some of the attributes associated with long term viability. The pattern in Palau has been similar, with relatively intensive fishing operations occurring in a given area but for no more than two or three years before closing. This pattern is indicative of problems regarding either the productivity of the resource or the distribution of benefits. In Palau's case, it appears that a lack of adequately productive fish stocks has been the most important constraint to viability. Several other reasons appear to have contributed to the termination of several operations, including inadequate interest and fishing effort by local fishermen and resentment by local communities at seeing species important as food used as feed. But a lack of adequate fishing grounds or fish stocks (sometimes expressed as concern over depletion of the stocks) was a reason cited for the termination of virtually every operation.

Just what impacts live food fishing has had on fisheries resources and their productivity is not clear, but there is strong evidence that live fishing operations have caused lasting impacts to grouper spawning aggregations. They may have also caused lasting impacts to populations of Napoleon wrasse, especially at Helen Reef, where a large number of fish was removed in a short time. It appears doubtful that the benefits of the fishery within Palau have exceeded the costs, especially after accounting for the external costs borne by the public. Either the costs of detrimental impacts to the resource were directly felt by the businesses through decreased production (and so they stopped), or the costs were felt by the public which then effectively transferred them to the businesses through public pressure to terminate operations.

1.4 PROSPECTS FOR MANAGEMENT

Effective management requires knowledge of the benefits and costs associated with an activity so that an appropriate portion of the costs borne by the public can be transferred to the appropriate parties. One general strategy for transferring public costs to a private enterprise is to strengthen and narrow (i.e.,

privatize) the property rights over the resource, such as through strengthening community control relative to national control. In the case of Palau, the relatively high level of local control over fishing grounds has clearly been an important determinant of which live reef fish operations have been able to operate where and for how long.

While strong local control over fishing grounds seems essential for management of any reef fishery, there are also important roles for the national government. These include supporting local-level management systems, providing fail-safe mechanisms (e.g., country-wide quotas or species restrictions), and, in cases where an activity is deemed detrimental to the country under any circumstances, effectively pre-empting local authority through strict restrictions (e.g., a prohibition on the export of live reef fish)

An overview of prospects for managing each of the two fisheries is given below, followed in Section 1.5 by more specific recommendations for action in the areas of outreach, national and state policy and management, industry, and research and monitoring.

Ornamentals

Between applicable state and national laws, particularly the aquarium collecting regulations, Palau's fishery for live ornamentals is probably as intensively managed as in any other Pacific Island country. Given the existing rules, the high level of compliance, the moderate size of the fishery, and the apparent lack of immediate threats to the resource, management can be judged as working reasonably well and not in need of major or urgent modification. A few relatively minor points for consideration are listed in Section 1.5.

Food Fish

Unlike the fishery for live ornamentals, the live food fish trade has had readily apparent negative impacts on the resource, including depletion of target stocks and dramatic and possibly irreversible impacts on spawning aggregations.

At least two former operations appear to have been stopped because of public pressure, expressed primarily through state and community leadership. This is positive in that it demonstrates that Palau's property regime-that is, strong state-level control over inshore resources-has been an effective mechanism for transferring what would otherwise be external costs to the industry. On the other hand, such transfer (through community reaction) has come only after a considerable amount of fishing and in some cases, substantial impacts to the resource. For that reason, it is recommended that the national government play a stronger role in managing the fishery, as it does in the fishery for ornamentals.

It appears that the best national policy would be to stop further development of the industry, and the best way to bring that policy would be through strict restrictions on the export of reef resources. Reasons include:

- Given current prices, technologies, and airline routes, the prospects for even short-term profitability appear marginal, at best.
- Although the lack of profitability is not in itself a good reason for government intervention, the fact that new operations keep starting up and subsequently failing, with negative impacts to the resource, is.

- The possibility of the fishery bringing net benefits to Palau appears remote if external costs of resource degradation or the risk of such degradation are added to the marginal profitability.
- Although the costs and risks associated with resource degradation could be minimized through government intervention (and transferred to the industry through restrictions and fees), the costs of doing so would be great.
- The scale of export required for profitability appears to be great relative to what Palau's resources can sustainably produce.
- Compared to the net value of the resource in the live food trade, alternative values appear to be great. These include the values from domestic consumption, diving and fishing by tourists, and biodiversity, as well as option value (the value of retaining future opportunities to use the resource).

In case this policy is not adopted and the fishery is left open, there are a number of recommended strategies, listed in the following section, that might help protect the resource and encourage a more efficient and sustainable fishery.

1.5 RECOMMENDATIONS FOR FUTURE ACTION

Outreach

1. Produce and disseminate educational materials, such as fact sheets and videos, on relevant topics about reef fish resources. Such topics should include: the findings and implications of the recent grouper aggregation study; the actual and potential productivity of Palau's reefs; trends in harvest and other uses, the various and competing uses of reef fish; forecasted growth of those uses; and implications with regard to exporting reef fish and other resources. A central message should be that keeping the resources in Palau is, with some exceptions, sound precautionary policy.

National Policy and Management

1. Seek resolution of debate over the bill that would prohibit the export of reef fish, and introduce a modification of that bill, with exemptions and controls for ornamental products, bioprospecting and research, and the export of reef products for non-commercial purposes.
2. In the event that the national government pursues a policy of allowing live reef food fishing for export, the management regime for the fishery should be strengthened. This should include adoption of a set of regulations that would establish a permit system and related provisions for any reef fishing for export for commercial or research purposes. The system should be modeled on, and perhaps incorporated into, the existing system for the ornamentals fishery. It should provide, among other things, permit requirements for export, prohibitions on the export of all but specific target species, quantitative limits on catch, effort, and/or exports, and requirements for permission from the states to fish. It should also include mechanisms to ensure that the full costs of management are transferred to the industry, through such means as permit fees.
3. Strengthen national government enforcement of laws applicable to the live reef food fishery. This should include:
   - regular inspections of exports;
   - enforcement of reporting requirements;

- on-water and in-water enforcement of area, method, and season restrictions (possibly through vessel observers if warranted);
- better enforcement of customs laws that require vessel clearance through Koror;
- minimization of poaching by foreign live food fish vessels through adequate patrols, particularly in the Southwest Islands and the far northern reefs; and
- better coordination among the Ministries of Resources and Development, Administration, and Justice.

4. Further consider the pros and cons of extending the grouper fishing closure through the month of August, or even September (depending on whether exports of food fish are prohibited and how tightly the fishery is otherwise controlled).

5. The ornamentals industry should be forced to spread out geographically as part of the permitting process.

6. If evidence is found that suggests negative impacts to particular ornamental species, adopt species-specific quotas on catch and/or export, using the rule-making mechanisms of the collecting regulations.

7. Improve national-state co-management of inshore marine and fisheries resources in general, through measures such as national laws that would clarify jurisdictional authority and that would create a cooperatively managed system of protected areas.

8. Pursue policies that encourage development of the local market for live reef fish.

9. Every few years, and with public input, re-evaluate the policy of allowing only Palauan ornamental collectors.

10. Consider relaxation of the definition of "cultured" as needed to facilitate development of low-impact culturing of hard corals, soft corals, tridacnid clams, and sponges.

11. Ensure that adequate mechanisms are in place to prevent the export of incidental species, including both illegal (e.g., sea turtles and tridacnid clams) and legal species (e.g., reef sharks).

State Policy and Management

1. Strengthen the fishing permit systems of the states, particularly Koror, Kayangel, Ngarchelong, and Peleliu, with the inclusion of permit requirements for any person or company that extracts and exports marine resources or marine information for commercial or research purposes. Include, as well, mechanisms for charging appropriate fees and providing additional terms of access through contractual agreement.

2. Provide support to the states and to their partners with local conservation area initiatives, including:

   - technical, legal, and financial support for Ebiil Conservation Area;
   - discussions with Ngarchelong regarding the possibility of providing stricter protection for the aggregation site at Western Entrance; and
   - management of the Ngeremeduu Conservation Area, particularly regarding the management of fishing and the Toachel Mlengui aggregation site.

3. Ensure that the ornamentals and live food fisheries are in the management plan for the Rock Islands, considering such options as:
   - closed areas and/or open zones for collecting ornamentals;
   - mariculture zones for ornamentals and other products; and
   - protection of aggregation sites from some or all fishing, including Mutiaur, Denges, Siaes, and Rebotel.
4. In cooperation with the national government, seek rationalization and harmonization of state policies and laws affecting fisheries-for-export, including permit systems and method restrictions.

Industry

1. Support as needed the efforts of the Marine Aquarium Council to develop a certification program for ornamentals.
2. Ensure that the local partners of any new live food fish operations are adequately educated on the impacts of the trade and best practices for fishing, handling, and fishery management.

Research and Monitoring

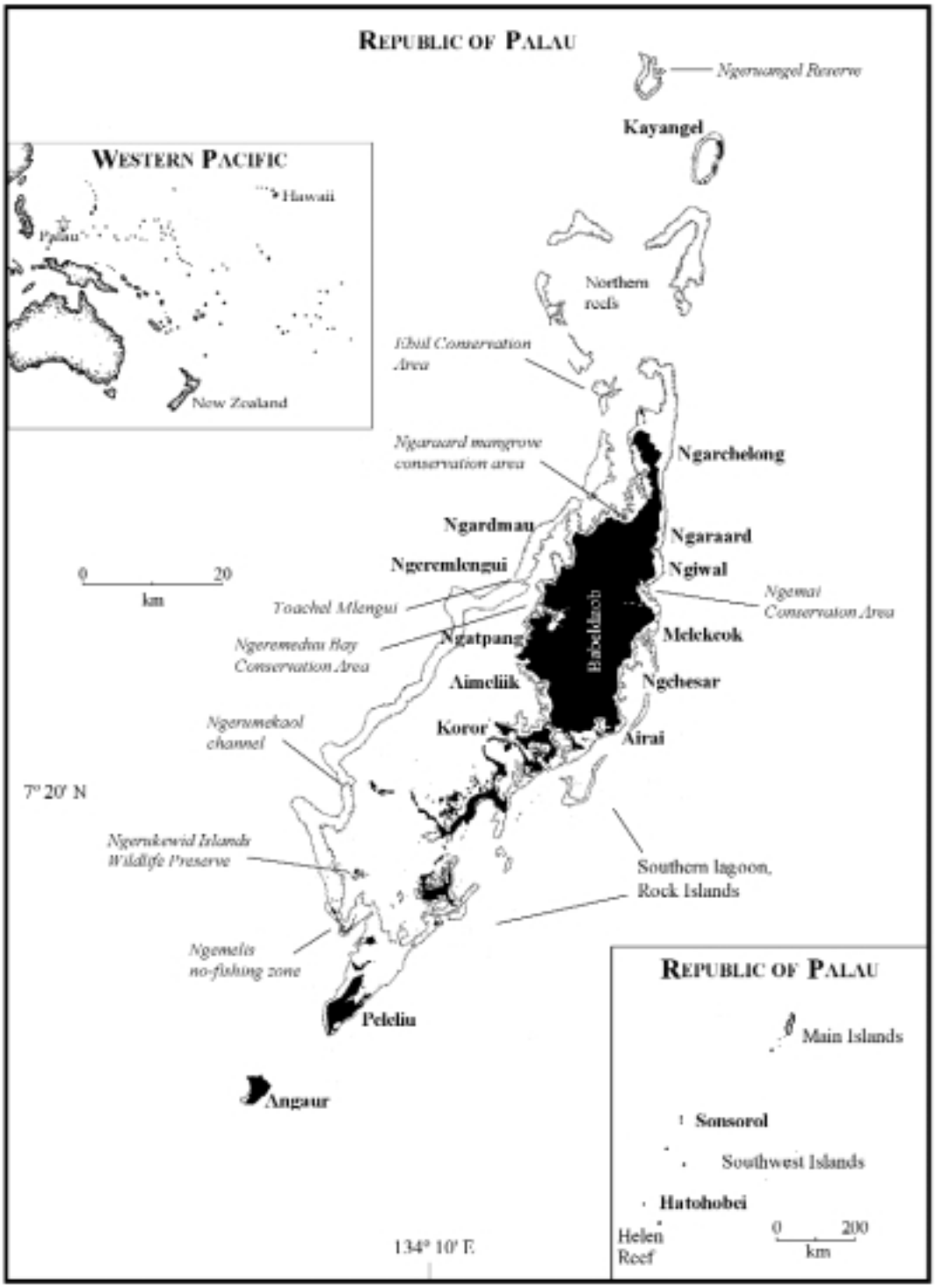
1. More rigorously assess the benefits and costs of export-based reef fish fisheries, particularly for live reef food fish. The assessment should take advantage of general analyses done in the region, complemented with Palau-specific information as necessary. Key elements to take into account include the productivity and vulnerabilities of target resources, prices, operating costs, competing uses of target resources, the needs and aspirations of local communities, and the capacity to cost-effectively manage the fishery.
2. Assess the costs and benefits of achieving full compliance with the catch and effort reporting requirements of the aquarium collecting and marine export regulations, and seek compliance as appropriate. This could be achieved through logbook systems to collect catch and effort data by area, and through analysis of export, catch, and effort data to detect impacts on particular species.
3. To the extent that the national government allows the live food fish fishery, conduct the analyses necessary to set limits on entry, effort, catch, seasons, or other necessary controls. Also, assess the relative advantages of a management framework that would encourage pulse fishing (versus steady fishing) and fishing on aggregations.

Conduct cost-effective monitoring of spawning aggregations, including:

- develop standardized and site-specific monitoring protocols;
- develop analytical capacity and procedures, including automated analytical tools;
- develop the scientific and management capacity of Koror State;
- conduct occasional training courses in underwater fish monitoring methods; and
- develop an effective team of underwater monitoring specialists across all agencies, organizations, and jurisdictions.

Figure 1. Map of Palau

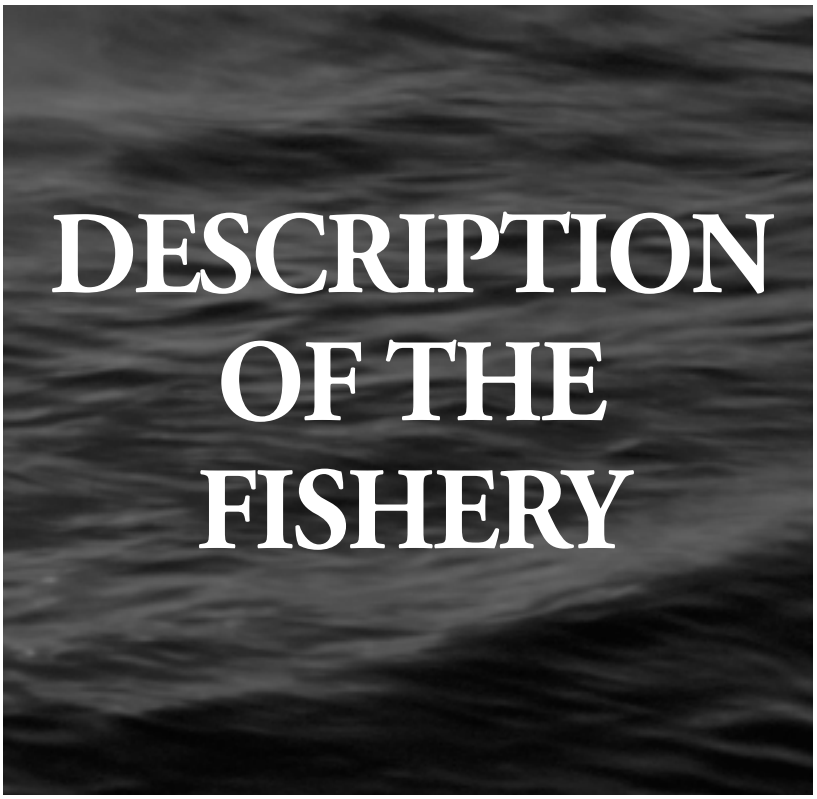
• State names are indicated in **bold**, marine protected areas are in *italics*, and other place names are in regular font.



INTRODUCTION

During the last 15 years at least three marine ornamental export businesses and five live reef food fish export businesses have established themselves in Palau. All but one have gone out of business or left the country. The up-and-down history of these fisheries and the apparent demise of so many businesses raise many questions about the industry-about the productivity of the resources, stability of demand, distribution of profits and economic rent, government control of the industry, and community control of fishing grounds.

This report will address those questions through a description of the history of the live food and ornamental fisheries in Palau (Section 2), followed by a summary of Palau's current management regime (Section 3) and assessments of the viability of the two fisheries (Section 4). Management strategies will then be discussed (Section 5), followed by more specific recommendations for action (Section 6). The recommendations focus on national and state-level policy and management, but also address corollary needs, including outreach, monitoring, and research.


DESCRIPTION
OF THE
FISHERY

2. DESCRIPTION OF THE FISHERY

Table 1 is a summary history of Palau's live reef fish fisheries, using the best available estimates of export volumes.

Table 1. History of the live reef fisheries of Palau

Year	Ornamental Products			Food Fish		
	Number of Exporting Operations	Finfish Exports (1,000 pieces)	Invertebrate Exports (1,000 pieces)	Number of Exporting Operations	Exports (mt)	Location
1984	0	0	0	1	75	South
1985	0	0	0	1		
1986	0	0	0	1		
1987	0	0	0	1		
1988	0	0	0	1		
1989	0	0	0	1	50	Helen
1990	1	2		1		
1991	1	100		0	0	
1992	1	200	20	0	0	
1993	1	100	20	1	0	Helen
1994	1	100	40	2	20+4	Helen+North
1995	1	100	40	2	20+4	Helen+North
1996	0	0	0	1	4	North
1997	0	0	0	0	0	
1998	1	0	3	0	0	
1999	1	10	2	1	2	North
2000	1	58	12	0	0	

- Some of the export estimates are very rough; see Section 2 for further details, methods, and qualifications.
- The food fish figures include chilled and frozen reef fish shipped incidentally to live fish.
- Year-2000 estimates are full-year (partial-year data have been extrapolated through the whole year).
- These figures do not include exports made directly by the Palau Mariculture Demonstration Center (PMDC), a government entity that exported cultured ornamental tridacnid clams to the U.S. market. Clams bought from the PMDC and exported by private companies are included.
- Exporting of ornamental products occurred prior to 1990, but apparently the volumes were low and the companies short-lived.
- "South" refers to the southern lagoon, "Helen" refers to Helen Reef in the Southwest Islands, and "North" refers to the northern reefs.

2.1 THE REGIONAL PERSPECTIVE

Ornamentals

The world's trade in marine ornamental fish has been growing rapidly, especially with new technology and the growing popularity of "mini-reefs"-home aquaria that more closely mimic coral reef ecosystems than traditional fish tanks. They typically include a wide variety of living components, including live rock and sand, invertebrates, and soft and hard corals-as well as fishes. Baquero (1999) estimated that about 10 percent of the ornamental fishes sold annually were marine species and cited estimates that 10 to 35 million fish were traded annually. Annual retail sales of marine ornamentals in the U.S. and Europe, which make up most of the market, have been estimated at $200 million, about one-fourth of retail sales of marine and freshwater fishes combined (Baquero 1999). Price data provided in Baquero (1999) suggest that the corresponding export value would be about one-eighth the retail value, or about $25 million. The Philippines and Indonesia supply about 85 percent of the livestock to the major markets, with Florida, Hawaii, and countries of the Pacific, Indian Ocean, and Caribbean supplying the remainder. Pyle (1993) estimated that Pacific Island countries (Forum Fisheries Agency member countries) provided 4 to 10 percent of the global supply of marine ornamental fishes. If these estimates are correct, then Palau, exporting 100,000 fishes per year, as it has done in a "typical" recent year, contributes about 6 percent of the Pacific Island countries' total, or roughly one-half of 1 percent of the global total.

Pyle (1993) described the species composition of ornamental finfish exports from Pacific Island countries. Damselfishes and angelfishes were the most important in terms of numbers (29% and 24%, respectively), followed by butterflyfishes (11%) and wrasses (7%). Angelfishes were by far the most important in terms of revenue (46%), followed by damselfishes (13%), wrasses (12%), and butterflyfishes (10%). Palau's contribution to the finfish trade has deviated somewhat from these regional averages with a predominance-both in numbers and revenues-of damselfishes.

Palau has also been an important producer of marine invertebrates, but its relative contribution to the global trade is difficult to assess because of a lack of trade data on invertebrates. It is known that Pacific Island countries supply the bulk of hard corals, live rock and sand, and tridacnid clams (Baquero 1999). This has become increasingly true since live rock collection was banned in Florida and U.S. federal waters. Important Pacific Island exporting countries have included Australia, Fiji, Tonga, Vanuatu, the Solomon Islands, Papua New Guinea, and Palau. Although Palau was probably a very important supplier of live rock and sand and possibly hard corals during part of 1994, subsequent prohibitions have caused exports of those products to virtually cease. Palau is probably a relatively important supplier to the U.S. market of tridacnid clams, soft corals, and other invertebrates.

Food Fish

The global trade in live reef food fish is centered in Hong Kong. In addition to being a very important market, Hong Kong also serves as a conduit to other areas of China, to which 55 to 60 percent of Hong Kong imports are re-exported (Chan 2000a). Taiwan, Singapore, and Japan also import live reef fish. According to Johannes and Riepen (1995), fishing for live fish spread through the South China Sea in the late 1960s and to the Philippines in the mid 1970s. In 1984 Palau was the first Pacific Island country to be targeted. By the late 1980s, Indonesia was becoming important as a fishing ground, and it is

currently the largest supplier (Lau and Parry-Jones 1999). The trade has spread to the Indian Ocean and to various Pacific Island countries, including Australia, the Solomon Islands, the Marshall Islands, Kiribati, Fiji, and Papua New Guinea.

Monitoring the trade has only recently begun in earnest, so it is difficult to describe the expansion of the fishery or Palau's contribution to it. An analysis of the trade in 1997 yielded an estimate of Hong Kong live iiireef food fish imports of 32,000 mt (Lau and Parry-Jones 1999). Chan (2000a) put annual Hong Kong imports at 30,000 to 35,000 mt. In 1995 Johannes and Riepen (1995) put a conservative estimate on the trade of wild-caught live reef food fish of 20 to 25,000 mt. At its peak of about 25 mt exported per year, Palau therefore contributed about one-tenth of 1 percent of the trade.

Lau and Parry-Jones (1999) estimated the wholesale value of the industry in the region to be about $500 million and Chan (2000a) estimated about the same at $490 million, implying an average wholesale value in Hong Kong of $15 to $20 per kilogram (kg).[1] Chan (2000b) reported that since the Asian economic downturn in 1997, wholesale and retail prices have declined by about 50 percent, and as a consequence, more than 20 percent of live reef fish operators have gone out of business. Chan *(ibid)* reported that prices decreased further-at least for brief periods-in response to several incidents involving imports of large numbers of ciguatoxic fishes.

Palau's interest in the trade has been limited to the capture and export stages of the value chain, so its "share" of the fishery can only be discussed in terms of ex-vessel and export values, which have been roughly one fourth and one half of the wholesale value, respectively.

2.2 ORNAMENTALS

There was apparently a small amount of commercial exporting of ornamental marine organisms prior to 1990, but the first regular exporting operation appears to have been Palau Aquatics, started in 1990. Four years later the company changed hands, took the name Palau Biotech, and came under new management. That company operated until 1996, when it folded. A new company, Belau Aquaculture, started exporting lagoon-farmed soft corals in late 1998. It changed ownership in 1999 but kept the same management. Belau Aquaculture is currently the only company catching or exporting ornamental marine organisms on a commercial scale.

The government of Palau, through its Palau Mariculture Demonstration Center (PMDC),[2] has also been an important exporter of ornamental products, selling its cultured tridacnid clams both directly and through other local companies to the U.S. market since about 1991.

It appears that most collecting of ornamentals has occurred in the waters of Koror, undoubtedly in part because of the proximity to the holding and packing facilities, all of which have been in Koror. At least two companies have been licensed by other states, including Airai and Ngchesar, and collecting has been reported to take place as far north as Melekeok (Rochers and Matthews 1992).

[1] The Hong Kong wholesale prices reported by Lau and Parry-Jones (1999) and Chan (2000a), ranging from $20/kg for the least expensive groupers to about $100/kg for the highest priced species, do not reconcile with these estimates of import volume and wholesale value, unless a large fraction of imports are lost before wholesale. It should be noted that only non-Hong Kong registered vessels are required to declare their imports.

[2] Until 1994 PMDC was known as the Micronesia Mariculture Demonstration Center.

A history of the fishery is given below, company by company. Where not attributed to published sources, information came from personal communication with sources such as the principals in specific operations. These and other important contacts are listed in Appendix 2. Additional sources of information on the fishery include the Division of Marine Resources (DMR) (no date), Rochers and Matthews (1992), Graham (1995), and FFA/DMR (1995).

Palau Aquatics

Palau Aquatics started in 1990 under the ownership of Polycarp Basilius and Willie Tan. It was managed by Sharron and operated out of a facility on Malakal in Koror. The company changed hands and became Palau Biotech in early 1994. Rough estimates of exports by Palau Aquatics are given in Table 2.

Table 2. Exports of Palau Aquatics

	Number of Pieces		Gross Revenues ($)[3]	
	Finfish	Invertebrates	Finfish	Invertebrates
1990	2,000		2,000	
1991	100,000		100,000	
1992	200,000	20,000	120,000	40,000
1993	100,000	20,000	70,000	70,000

• Estimates roughly derived from partial-year data reported in DMR (no date) and FFA/DMR (1995).

The export estimates for 1990 and 1991 are very rough and the species composition for those years is not known. It is clear, however, that finfish and invertebrates were important starting no later than 1992. Exports in 1992 and 1993 included cultured tridacnid clams from the PMDC. Soft corals and hard corals do not appear in 1992 export data but they do appear in 1993 data (see FFA/DMR 1995 for incomplete data). Palau Aquatics did not sell anything it called "live rock," but in 1993 sold a product called "polyp rock," which consisted of dead substrate-generally tridacnid clam shells covered with zooanthids. The top selling finfish and invertebrate species in 1992 and 1993 are shown in Tables 3 and 4, respectively.

[3] All dollar figures in this report are in nominal terms-that is, they have not been adjusted for inflation.

Table 3. Top-selling finfish species, Palau Aquatics

Species Name			% of Finfish Sales	
Scientific		**Common English**	**By Number**	**By Revenue**
Chrysiptera cyanea	(Pomacentridae)	Blue chromis	52	21
Chromis atripectoralis	(Pomacentridae)	Green chromis	17	6
Dascyllus aruanus	(Pomacentridae)	three-stripe damsel	5	
Thalassoma quinquevittatum	(Labridae)	Rainbow parrot wrasse	2	5
Odonos niger	(Balistidae)	Niger trigger	1	8
Pognocuius zebra		Zebra goby	1	
Chaetodon auriga	(Chaetodontidae)	Auriga butterfly	1	
Thalassoma hardwicke	(Labridae)	six-bar wrasse	1	
Zebrasoma veliferum	(Acanthuridae)	Sailfin tang	1	4
Pseudanthias pascalus	(Serranidae)	Purple queen	1	3
Paracanthurus hepatus	(Acanthuridae)	Blue tang		4
Scarus spinus	(Scaridae)	Pygmy parrot		3
Chaetodon semeion	*(Chaetodontidae)*	*Semeion butterfly*		*2*
Chaetodon ephippium	(Chaetodontidae)	Saddleback butterfly		2
		Total (top ten only)	**82**	**62**

- A blank cell indicates that the species was not among the top ten.
- From export data for 3 months of 1992, as reported in DMR (no date); names are as used there.
- About 175 species of finfish were reported exported during this 3-month period.
- It appears that "Pognocuius zebra" is not the correct name-it is not clear what species that was.

Table 4. Top-selling invertebrate species, Palau

Species Name		% of Invertebrate Sales	
Scientific	**Common English**	**By Number**	**By Revenue**
Tridacna derasa	derasa clam, 9cm	22	34
Marmarostoma argyostoma	turbo grazer	7	1
Calcinus laevimanus	hermit crab	6	
Tridacna gigas	gigas clam, 7cm	5	8
Diadema sp.	royal sea urchin	4	1
Haliotis asinina	abalone shell	3	2
Hippopus hippopus	hippopus clam, cultured	3	6
Phyllidia spp.	assorted knobby sea slugs	3	1
Phyllidia sp.	red blood sea hare	3	1
Pardanus pedunculatus	hermit crab w/ anemone	2	1
Stenopus hispidus	rare shrimp		1
	Total (top ten only)	**59**	**56**

- A blank cell indicates that the species was not among the top ten.
- Estimates are from export data for 3 months of 1992, as reported in DMR (no date); names are as used there.
- These data may not fairly represent all exports, as recollections of Sharron suggest that blue star (*Linckia laevigata*), royal urchin (*Mespilia sp.*), serpent star (*Ophiarachna incrassata*), and red star (*Fromia sp.*) were among the dominant species.
- Incomplete data in FFA/DMR (1995) indicate exports of soft corals, hard corals (limited to "fleshy" corals such as *Fungia* and *Euphyllia spp.*), and "polyp rock" (zooanthids on substrate) in 1993 but not in 1992.
- Sixty-four invertebrate products (probably as many as 100 species) were reported exported during this 3-month period.

Palau Biotech

In late 1993 or early 1994 the Palau Aquatics facility was leased to Shinji Chibana, who took ownership of the business as Palau Biotech. The operation supplied a large variety of ornamental products to the U.S., including finfish, live rock, hard and soft corals, and a variety of other invertebrates.

As shown in Table 5, exports in 1994 were dominated in number by finfishes, but invertebrate species brought in more revenue. Export volumes in 1995 are unknown; they are assumed in the summary Table 13 to be the same as in 1994.

The company went out of business in early 1996. According to Chibana, most of the profits came from live rock, hard and soft corals, and sand. The other invertebrates and finfishes were provided in order to satisfy customer demand, but in general, they could not compete with comparable products from Asia and were not in themselves profitable.

Table 5. Exports of Palau Biotech

	Number of Pieces		Gross Revenues ($)	
	Finfish	**Invertebrates**	**Finfish**	**Invertebrates**
1994	100,000	40,000	80,000	120,000
1995	100,000	40,000	80,000	120,000

- Estimates from sales data provided by Palau Biotech for the period 1 January-14 December 1994, supplemented with data from Eichhorst (1994).
- No data for 1995 are available; these estimates are based on the presumption that operations in 1995 were similar to 1994 (although beginning in January 1995 the export of hard coral, live rock, coralline sand, and soft coral planted on coralline bases would have been prohibited).

Tables 6 and 7 show the dominant finfish and invertebrate species exported in 1994.

Table 6. Top-selling finfish species, Palau Biotech

Species Name			% of Finfish Sales	
Scientific		**Common English**	**By Number**	**By Revenue**
Chrysiptera cyanea	(Pomacentridae)	blue damsel	37	
Chromis atripectoralis	(Pomacentridae)	green chromis	14	
Sphaeramia nematoptera	(Apogonidae)	pajama cardinal	7	
Salarais fasciatus	(Blenniidae)	sailfin blenny	4	
Pomacentrus coelestis	(Pomacentridae)	electric blue damsel	3	
Dascyllus aruanus	(Pomacentridae)	three-stripe damsel	3	
Centropyge bispinosa	(Pomacanthidae)	coral beauty angel	2	
Dascyllus melanurus	(Pomacentridae)	four-stripe damsel	2	
Centropyge bicolor	(Pomacanthidae)	bicolor (oriole) angel	2	
Thalassoma quinquevittatum	(Labridae)	rainbow parrot wrasse	2	
		Total (top ten only)	**75**	

- From sales data provided by Palau Biotech for the period 1 January-14 December 1994; names are as used there.
- About 150 species of finfish were reported exported during this 12-month period.
- No data were available on revenue by species.

Table 7. Top-selling invertebrate species, Palau Biotech

Species Name		% of Invertebrate Sales	
Scientific	**Common English**	**By Number**	**By Revenue**
Tridacna derasa	derasa clam	14	
Sinularia sp.	green & brown sinularia	12	
Sarcophyton trocheliophorum	leather coral	11	
Micropipus sp.	sally light foot crab	6	
Marmarostoma argyrostoma	turbo grazer	5	
Linckia laevigata	blue starfish	4	
Calcinus sp.	blue stripe hermit crab	4	
Tridacna crocea	Crocea clam4		
Toxopneustes sp.	Palauan rainbow urchin	3	
Hippopus hippopus	Hippopus clam	3	
	Total (top ten only)	**65**	

- From sales data provided by Palau Biotech for the period 1 January-14 December 1994; names are as used there.
- Not appearing in the top ten sellers but exported in 1994 in substantial quantities were hard corals and live rock; the U.S. Fish and Wildlife Service estimated imports to Los Angeles of at least 1,300 pieces of hard coral and 7,000 pounds of live rock during a 3-month period in early 1994 (Eichhorst 1994).
- About 75 species of invertebrates were reported exported during this 12-month period.
- No data were available on revenue by species.

According to FFA/DMR (1995), Palau Biotech had permits to collect in the states of Koror, Airai, and Ngchesar, to which it paid $500 to $750 per year in fees.

Chibana asserted that it was the unstable and increasingly strict government regulations that drove the company out of business in early 1996. The company was first impacted in 1994 by the provisions of a new law (RPPL 3-61) that prohibited commercial exports of reef finfish from March through July. Palau Biotech received warnings from both Palau and the U.S. (which, in enforcing its Lacey Act, stopped one of the company's shipments into the U.S. in May 1994) and eventually complied with the law.[4] The short-lived RPPL 3-61 was repealed with the enactment of the Marine Protection Act (MPA) in May 1994. The MPA directly regulated the ornamentals fishery through its *Regulations on the Collection of Marine Resources for Aquaria and Research*, enacted in December 1994. Most critically, the new regulations provided that hard corals, live rock, sponges, and tridacnid clams could not (with some exceptions) be exported from Palau. The production of soft corals was also affected, as soft corals were typically planted on small pieces of coralline substrate, which could not be exported.

Palau Biotech was engaged in lagoon-farming and facility-farming of both hard and soft corals, which, if certified by the government as "cultured" or as having been taken incidental to permitted dredging, could have been legally exported. But no such certification or export was done. In fact, the farming done by the company fell far short of the definition of "cultured" set by the government. That definition was modeled on the strict concept of "captive bred" as applied to species listed CITES, which would require a nearly closed breeding and growing system.

New laws prohibiting the use of small mesh nets and compressed air presented a final hardship for the company by making it difficult to legally harvest ornamental finfish.

[4] The U.S. Lacey Act prohibits the import of fish or wildlife taken, possessed, transported, or sold in violation of any foreign law.

Belau Aquaculture

Based at a new facility at Malakal in Koror, Belau Aquaculture started exporting in early 1998 under the ownership of Shallum Etpison and the management of Larry Sharron. The business was at first based on soft corals lagoon-farmed at various locations in the waters of Koror, along with cultured tridacnid clams bought from the PMDC. According to Sharron, the El Niño-Southern Oscillation (ENSO) event of late 1998 killed about 90 percent of the company's stock of soft corals being farmed. At that point the company shifted to lagoon-farmed sponges and soon after, to wild finfishes and invertebrates. Problems with water quality in the holding tanks at the facility in Malakal caused relatively high rates of mortality of finfishes.

In February 1999 the business was sold to Victor Yano and Jennifer Sugiyama and in November 1999 it moved to a new and larger facility in Ngerbeched near M-dock in Koror. Current export products include wild finfish and invertebrates, PMDC-raised tridacnid clams and trochus shell, and lagoon-raised soft corals and sponges. Table 8 summarizes the export activities of Belau Aquaculture.

Table 8. Exports of Belau Aquaculture

	Number of Pieces		Gross Revenues ($)	
	Finfish	**Invertebrates**	**Finfish**	**Invertebrates**
1998	0	2,500	0	8,500
1999	10,000	2,000	10,000	4,000
2000	58,000	12,000	78,000	26,000

• Estimates from sales data provided by Belau Aquaculture; year-2000 data have been extrapolated through the entire year.

Although Belau Aquaculture was at first based on farmed invertebrates, by 1999 wild finfishes became its dominant product in terms of both numbers and revenue. This contrasts with the experience of Palau Biotech, which relied more on invertebrates. Sales records of Belau Aquaculture indicate that out of a total of about 35,000 pieces exported in the first half of 2000, 83 percent were finfishes and 17 percent were invertebrates. In terms of revenue, finfishes contributed 75 percent and invertebrates 25 percent.

As noted in Table 9, the top-selling species in 2000, the blue damselfish or blue devil, *Chrysiptera cyanea,* comprised 31 percent of all finfish sales by number and 17 percent by revenue. The table shows the top ten selling finfish species for the first half of 2000, both by number and by revenue. It can be seen that damselfishes (Pomacentridae) were the most important family, particularly in terms of numbers but less so in terms of revenue.

As can be seen in Table 10, the top-selling invertebrate species by number was the blue starfish, *Linckia laevigata.* But by revenue the giant clam *Tridacna derasa*, cultured at the PMDC, was far more important, comprising 24 percent of invertebrate sales. The table shows the top ten selling invertebrate species for the first half of 2000, both by number and by revenue.

Table 9. Top-selling finfish species, Belau Aquaculture

Species Name			% of Finfish Sales	
Scientific		**Common English**	**By Number**	**By Revenue**
Chrysiptera cyanea	(Pomacentridae)	blue damsel	31	17
Chromis viridis	(Pomacentridae)	green chromis	14	4
Dascyllus melanurus	(Pomacentridae)	four-stripe damsel	7	3
Pomacentrus sp.	(Pomacentridae)	neon damsel	6	4
Dascyllus aruanus	(Pomacentridae)	three-stripe damsel	5	
Pomacentrus pavo	(Pomacentridae)	blue chromis	5	
Pomacentrus moluccensis	(Pomacentridae)	lemon damsel	4	
Centropyge bispinosa	(Pomacanthidae)	coral beauty	2	4
Chromis margaritifer	(Pomacentridae)	bi chromis	2	
Thalassoma quinquevittatum	(Labridae)	parrot wrasse	2	3
Naso vlamingii	(Acanthuridae)	vlamingii tang		7
Nemateleotris helfrichi	(Microdesmidae)	helfrich goby		5
Scarus spinus	(Scaridae)	pygmy parrot	4	
C*entropyge loricula*	(Pomacanthidae)	flame angel		2
		Total (top ten only)	**78**	**54**

- A blank cell indicates that the species was not among the top ten.
- From sales data provided by Belau Aquaculture for the period 1 January-26 July 2000; names are as used there.
- A total of 186 finfish products were exported during this 7-month period.
- *Chromis viridis* is similar to *C. atripectoralis.* Palau Aquatics and Palau Biotech reported selling many more of *C. atripectoralis* than *C. viridis*, suggesting perhaps that one or more of the three companies misidentified or mixed the two species.

Table 10. Top-selling invertebrate species, Belau Aquaculture

Species Name		% of Invertebrate Sales	
Scientific	**Common English**	**By Number**	**By Revenue**
Linckia laevigata	blue star	11	5
Tridacna derasa	derasa clam, cultured	8	24
Mespilia sp.	royal urchin	8	4
Echinometra sp.	tux urchin	7	3
Ophiarachna incrassata	serpent star	5	3
Ophiarachnella sp.	brittle star	4	
Trochus sp.	trochus snail, cultured	4	
Asthenosoma varium	rainbow urchin	4	5
Turbo petholatus	turbo, rare	3	5
Turbo sp.	turbo, common	3	
Siphamia sp.	urchin		5
Gomphia sp.	deep star		4
Sarcophyton sp.	leather coral, cultured		3
	Total (top ten only)	**59**	**61**

- A blank cell indicates that the species was not among the top ten.
- From sales data provided by Belau Aquaculture for the period 1 January-26 July 2000; names are as used there.
- A total of 83 invertebrate products were reported exported during this 7-month period.

The product list of Belau Aquaculture includes about 350 items (a given species might be sold as several different products, such as by sex, size, and whether it is part of a mated pair). Eighteen of those products are described as being "maricultured," including four species of tridacnid clams, trochus shell, four species of soft coral, three sponges, a gorgonian, and a zooanthid.[5] Neither hard corals nor live rock have been exported. Sharron reported that due to a huge increase in supply of live rock from Fiji, the price had dropped to 25 or 30 percent of what it was about five years earlier. Baquero (1999) reported the export prices of live rock from various Pacific Island countries to range between $1.25 and $2.00 per kilogram. Sharron said that regardless of Palau's restrictions on export of live rock, with the high freight rates from Palau his company could not break even on live rock or compete with sources in Fiji, which had shipping rates of about $2.10 per kilogram to the U.S. (Baquero 1999).

While Chibana of Palau Biotech noted that Palauan finfish products could not compete with fish from Asian sources, Sharron said that Palau does have a competitive advantage for certain species that have peculiar characteristics or are relatively abundant in Palau. Those species are the blue damselfish (*Chrysiptera cyanea*)-the male of which Sharron described as the "signature fish" of Palau[6]-the vlamingii tang (*Naso vlamingii*), and the parrot wrasse (*Thalassoma quinquevittatum*). Sharron also noted that ornamental fish exports recently ceased from the Solomon Islands, which was an important competitor for Palau's specialty species, such as the male *Chrysiptera cyanea*. Belau Aquaculture advertises its products as being hand-caught (the principals reported that most fish are caught by scoop net or fence net, and that compressed air is sometimes used), which puts a small premium on the product. A final advantage cited by Sharron is that while most exporters in Asia are wholesalers, Belau Aquaculture actually does the collecting, making it better able to rapidly respond directly to the needs of its customers.

Belau Aquaculture has one main customer, a wholesaler in Los Angeles. Aside from occasional orders from public aquaria, its relationship with that customer is exclusive, and it provides about one third of the needs of that customer. Belau Aquaculture is currently working for the Palau International Coral Reef Center to stock the Center's new aquarium with fishes and other organisms, including live rock (only the export of wild live rock is prohibited, not its collection, possession, or sale.)

The company typically makes one shipment per week. Freight charges, which Belau Aquaculture passes from its providers to its customers, constitute about 50 percent of total company revenues. Those charges include the $3.50-per-kilogram charge of the airline and the fees of the freight forwarder.[7] Packaging materials and service charges make up another 5 to 10 percent of revenues, leaving income from live product in the range of 40 to 45 percent of the total.

The company currently employs nine people, four of whom are Palauan. The company has two collectors licensed by the national government; both Palauan, as required by law. They are "assisted" by the Filipinos in the water. The company has permits to collect in two states, Koror and Airai, to which it pays about $600 per year, but it collects mostly in the waters of Koror.

[5] Under the Marine Protection Act, the tridacnid clams and sponges must be certified as "cultured" in order to be exported.

[6] The distinctive yellow markings of the male *Chrysiptera cyanea* in Palau and other areas is lacking in the Philippines, and its markings in Palau differ from those in other areas. The special appeal of this fish is reflected in the difference in prices between males and females. Belau Aquaculture lists them at $1.25 and $0.20, respectively.

[7] Both the Philippines and Indonesia have air cargo rates to the U.S. of less than $3.00/kg.

With investments in additional facilities by its primary buyer, Belau Aquaculture is planning to expand in the next year and has a goal of tripling its exports.

2.3 FOOD FISH

The fishery for live reef food fish in Palau has been an off-and-on endeavor since the mid 1980s. The fishery can be described in terms of three main fishing grounds: the northern reefs of Palau's main islands (primarily Kayangel and Ngarchelong States), Helen Reef in the remote Southwest Islands (Hatohobei State), and the southern lagoon (primarily Koror State).

A brief history of the fishery is given below, area by area. Where not attributed to published sources, information came from personal communication with sources such as the principals in specific operations. These and other important contacts are listed in Appendix 2. Additional sources of information on the fishery include Kitalong and Oiterong (1991), FFA/DMR (1995), Johannes and Riepen (1995), Johannes *et al*. (1999), and Hoshina (1999).

Southern Lagoon

The recollections of individuals familiar with the live food fish fishery in the 1980s and early 1990s were found to be somewhat inconsistent. It appears that a foreign company, based either in Taiwan or Hong Kong, engaged in fishing and exporting live fish in Palau from 1984 to 1988, through a joint venture with several local partners. Fishing took place mostly in the waters of Koror, targeting at least two well known grouper aggregation sites, Denges and Ngerumekaol. The former was reported to have almost completely disappeared as a result of the fishing (Johannes *et al.* 1999).

Fishing also took place in the waters of Ngeremlengui on the west coast of Babeldaob, where there is another well known grouper aggregation area in the channel, Toachel Mlengui. Kitalong and Oiterong (1991) reported that about 54 mt of live fish were exported from 1984 through 1988. No information was found regarding the composition of species exported. One of the local partners involved during the last two years of the operation said that 7 mt were shipped quarterly. FFA/DMR (1995) reported that a local dealer estimated that 10 to 15 mt were exported quarterly from 1986 to 1988. As summary Table 13 shows, there was an intermediate estimate of 15 mt per year, or a total of 75 mt over the five years.

It was reported that the foreign company was ultimately denied access to the fishing grounds by individual states (FFA/DMR 1995) or by the national government (Johannes and Riepen 1995). Three reasons were cited for the termination of operations: local complaints about the use of reef fish to feed the groupers (Johannes and Riepen 1995), detrimental impacts to spawning aggregations, and the foreign partner's reneging on an agreement to train local fishermen that would have replaced the foreign fishermen within six months (Richards 1993). Johnny Gibbons, one of the local partners in the operation, reported that the waters of Koror State (in which they had permission to fish) were not sufficient to support the operation, and because they were not able to get permission from additional states, they quit fishing. Upon leaving Palau the foreign partner apparently turned to the islands of Yap as potential fishing grounds but failed to gain access. It then returned to Palau, where it set up operations at Helen Reef in the Southwest Islands, hundreds of kilometers from Palau's urban center of Koror (Richards 1993).

Helen Reef

At least two separate fishing ventures operated at Helen Reef in the last decade. The first operated sometime in the period 1989 to 1990, apparently led by the same foreign company that operated during the previous few years in the southern lagoon. This venture was originally done in partnership with or under agreement from the state of Hatohobei, with participation by local fishermen. Palauan sources recalled three fishing trips to Helen Reef that resulted in exports via carrier ship. The first trip included participation by local fishermen and the last two, after a disagreement between the foreign and local partners, had no local participation or permission. On the final known trip, in 1990, the foreign boat, the Palau Star, was caught poaching with 11 mt of live grouper and wrasse on board and the captain was subsequently prosecuted (Richards 1993).

It is not known exactly how much fish was caught or exported from Helen Reef during this period. It is clear that cyanide was used and that a large number of Napoleon wrasse (*Cheilinus undulatus*) was taken. Johannes and Riepen (1995) reported that five to ten tons of wrasse were taken. FFA/DMR (1995) reported that 1.5 tons of wrasse were confiscated from the foreign vessel caught poaching. Another source reported that fishing was so intensive that as many as five tons of fish were caught in a given day. There were three known fishing trips, each of which appears to have lasted no longer than two or three weeks. The first involved two carrier ships, the second and third trips involved only one. Given this evidence, along with the assumption that the carrier ships could hold 10 to 15 mt each and the possibility that perhaps as many as two additional shipments were made in addition to the three known ones, the total amount of live fish exported (or attempted to be exported) during the life of this operation was probably between 20 and 80 mt. A best estimate of 50 mt is used in the summary Table 13.

Although Helen Reef has been subject to fairly regular poaching by foreign boats, there have been no reports of poaching of live fish since the 1990 incident.

In late 1993 a new joint venture headed locally by Thomas Patris, presumably with a different foreign partner, and under agreement with Hatohobei State, started fishing for live fish at Helen Reef. Fishing went on for about two years. Based on various sources of information, it appears that at least 30 mt of live fish were delivered via at least five shipments by sea, starting in early or mid 1994 and ending in early 1996. It is possible that the total volume exported could have been as high as perhaps 50 mt. An intermediate estimate of 20 mt per year for two years is used in the summary Table 13.

The species composition of one shipment, in November 1994, was observed by personnel of the Division of Marine Resources, which described it as shown in Table 11. Also shown are the results from daily catch data recorded by the fishermen during the first three months of 1995, at the request of the government of Hatohobei. It should be noted that no quality control was done on the daily catch data so their accuracy is not known.

Table 11. Species composition, Helen Reef

Species	Percent Composition (by number)	
	Live Shipment (November 1994)	Daily Catch Data (January-March 1995)
Serranidae (groupers)		
Aethaloperca rogaa	present	present
Anyperodon leucogrammicus	present	present
Cephalopholis argus	present	third most dominant
Epinephelus fuscoguttatus	present	present
E. polyphekadion	60	second most dominant
E. corallicola (ID not positive)	present	
E. cyanopodus	present	
E. macrospilos	present	present
Epinephelus spp.		present
Plectropomus areolatus	10	*
P. laevis	5	present
P. leopardus	5	first most dominant *
Variola spp.	present	fourth most dominant
Lutjanidae (snappers)		
Lutjanus bohar	present	present
Lutjanus gibbus	present	present
Macolor sp.		present
Lethrinidae (emperors)		
Lethrinus erythracanthus	present	
Labridae (wrasses)		
Cheilinus undulatus	present	

- November 1994 shipment data from Division of Marine Resources unpublished data.
- Daily catch data provided by Patris.
- *P. areolatus* was almost never recorded in the daily catch log; it is likely that it was not distinguished from and was included with *P. leopardus*.

Based at Helen Reef was one mother fishing boat, the Sea Sprit, from which 14 small fishing boats operated. Fishermen included about six Palauans, eight to ten Filipinos, and three to six Chinese. The local fishermen were on salaries of $250 per month. Fishing was reported by the local partner to be done only by hook and line, although he said he was concerned that the foreign fishermen, if not properly overseen, would have used cyanide and dynamite-the latter presumably to catch feed fish or possibly fish to be exported chilled or frozen rather than live.

Patris said that a minimum of 5 mt was required for the carrier ship to come in and make a delivery to Hong Kong. The sizes of the five known shipments appear to have ranged from 4 to just over 7 mt.

Patris reported that mortality of fishes while being held was usually quite low-less than one-tenth of 1 percent per day. But, serious losses were occasionally suffered from the pens being ripped open by sharks. Mortality during loading and transport to Hong Kong was reported to be about 10 percent for the November 1994 shipment, but sources suggest that mortality may have been 50 percent or more for some of the subsequent shipments.

The feed requirements of the live fish are not known, but based on anecdotal data, 5 percent per day by weight seems to be a reasonable estimate. In addition to using dead groupers and the by-catch from line fishing, additional feed fish were caught by spear and trolling.

After the first year of fishing, Hatohobei State extended the company's permission to fish for another year, but apparently did so reluctantly, due to concerns about impacts on the reef's fish stocks. Hatohobei required the operation to submit detailed catch reports, and it retained the right to void the agreement at any time that it found the fish stocks to be seriously depleted. It also charged an annual fee of $1,500, plus $500 per shipment.

In early 1996, Patris, the local partner, stopped the operation, but not without pressure from Hatohobei State. Some of the likely reasons follow. First, Patris was becoming increasingly unhappy with the prices being paid by the Hong Kong partners, who consistently complained of poor quality fish and paid what were apparently the lowest going prices. Second, the catch rates during the two-year period reportedly declined dramatically, thus increasing fishing and feeding costs at the same time that buyers were asking for more and more fish. The perceived impacts on the stocks of groupers and other reef fish at Helen Reef also worried local interests, including both Patris and Hatohobei State. The state increasingly pressured the operation to pay higher access fees and to demonstrate that fish stocks were not being excessively impacted. The Marine Protection Act's four-month closure on grouper fishing and ban on the export of Napoleon wrasse also impacted operations.

In short, given the prices paid and the increasing costs of fishing and feeding the fish (due in part to diminishing fish stocks), along with the increasing pressure from the local government, Patris, and perhaps the foreign partners, found it uneconomical to continue to fish.

Northern Reefs

In late 1993 a joint venture set up a fish holding facility in Ngatpang State on the west side of Babeldaob. Fishing and exporting continued until early 1997. The local partner company was called Palau Fishing Industry, of which Santos Olikong was one of the principals.

Fishing took place primarily in the northern reefs in the waters of Kayangel and Ngarchelong, but also in the waters of several of the western Babeldaob states, as far south as Aimeliik. The company bought fish directly from local fishermen, and probably sometimes from the state fishing cooperatives. The company bought and exported both live and chilled and frozen fish, and always shipped by air.

Early in the operation the company maintained a 125-foot mother ship in the vicinity of Ngkesol Reef. The *Pristine I* served as a dormitory for the fishermen. The 60-foot supply boat, *Pristine II,* ferried fuel, supplies, and fish between the mother ship and Ollei, Ngatpang, and Koror. The company operated holding pens at the *Pristine I* and at Ollei. Small concrete holding tanks were maintained at Ngatpang, from where fish were trucked or shipped to a packing facility in Koror. Later in the operation the mother and supply ships stopped being used. Less fish consequently came from the northern reefs, relatively more fish came from the western states of Babeldaob, and total export rates appear to have decreased. Over the period of the operation, exports increasingly shifted from chilled and frozen fish to greater reliance on live fish.

The company made three 16-foot fishing boats available to the fishermen. Prices paid to fishermen depended on whether or not they used the company's boats.

Target species were caught by hook and line both at night and during the day. In cases where there was an urgent order from Hong Kong for chilled or frozen fish, the company would request the fishermen to spear the needed fish.

The company shipped to Hong Kong via Guam, with two available flights per week. The operation also tried going through Manila, but Olikong reported that the bribery costs in Manila were excessive. Shipping appears to have typically occurred two to four times per month. Because of the frequent shipments, the fish rarely needed to be held for more than two weeks and, in contrast with the Helen Reef operation, feed requirements were relatively small. Feed fish included dead target species, by-catch, and shark.

Olikong reported that fish were bought from as many as 100 local fishermen during the course of the operation. In 1994 only Palauans were fishing and crewing the vessels, with the exception of the Filipino captain of the mother ship. At that time, about five to ten fishermen from Ollei and Kayangel were fishing regularly for the company. In early 1995 at least four Filipino fishermen were hired by Kayangel State to supply fish to the company, and the Kayangel fishermen subsequently stopped fishing for the company. The reason given for hiring the foreigners was that there were not enough local fishermen fishing consistently enough to supply what the company needed to satisfy its buyers.

No detailed information on species composition is available. Observations of one small shipment of live fish in February 1995 and of fish being held at Ngatpang at various times were made by personnel of the Division of Marine Resources, as shown in Table 12.

Table 12. Species composition, Northern Reefs

Species	Percent Composition (by number)		
	Live Shipment (February 1995)	Live Holding (March 1995)	Live Holding (Various dates)
Serranidae (groupers)			
Cephalopholis argus			present
C. sexfasciatus	5		
Epinephelus. Fuscoguttatus			present
E. polyphekadion	15	dominant	
Epinephelus spp.	5		
Plectropomus areolatus	10	dominant	
P. laevis	2		
P. leopardus			60
Variola spp.			present
Labridae (wrasses)			
Cheilinus undulatus			present

- From Division of Marine Resources unpublished data.
- A blank cell indicates not known or not recorded whether present.
- The dominance of *Plectropomus leopardus* in the February 1995 shipment is odd because in Palau it is generally caught in smaller numbers than *P. areolatus*, as seen in the March 1995 observation of the holding tanks. It is unlikely that the composition of the February 1995 shipment reflected the composition of all live exports of this operation.

There are no clear records of the amount of fish exported by this operation or of how much was live versus chilled and frozen. Olikong reported that about 200 pounds of fish, net weight, per flight with one flight per week was the break-even point for the operation (but it was not clear how much of that would have to be live). He reported that the operation generally did not keep exports quite up to that rate. Assuming the rate averaged between 150 and 200 pounds per week, this would imply annual exports of live, chilled, and frozen fish of about 4 mt (as indicated in Table 13). This is consistent with cargo manifest records of Continental Air Micronesia, which showed a total of about 7 mt of fish, gross weight, being exported to Hong Kong in 1994. In 1994 most of the shipments were of chilled and frozen fish. Gradually more live shipments were sent, and according to Olikong, by mid 1995 about half of the shipments were of live fish. Among those, about half the fish died during the 20-hour trip to Hong Kong due to transshipment problems. At some point in 1995 the company virtually stopped shipping dead fish due to low prices. It also exported dried shark fin and some fish for public aquaria-including lionfish. There were occasional mortality problems in the holding pens, including losses due to sharks and thieves.

In 1995 fishermen were receiving $1.60 per pound for grouper and wrasse, regardless of whose boats they used, and $0.90 per pound for other species (unless they used a company boat, in which case they received only $0.60 per pound for these other species). The company was buying both live and fresh-dead fish at the same price, but planned to lower its price for dead fish (to be shipped chilled or frozen or sold locally) to $1.40/lb. There was no charge for fuel and oil if a company boat was used, and a charge of $12.00 per six-gallon tank if a private boat was used. The fishermen supplied their own bait. The company provided free room and board to the fishermen aboard *Pristine I*.

The operation stopped in early 1997. In 1994 Olikong had noted that he was having trouble getting fishermen to provide the company with enough fish. In 2000 he cited the main reasons for stopping the operation to be the high costs of transport, high mortality rates while shipping, and the lack of an adequate and consistent supply of fish. He traced the last reason to a lack of adequate fish stocks (rather than to disinterest on the part of fishermen). Although Olikong noted a depletion of fish in Palau's waters over the previous five to ten years, he did not believe that domestic fishing was a cause. Instead, he blamed poaching by foreigners and non-fishing causes such as global warming and boat engine exhaust.

In 1998 a second joint venture was set up with fishing focused in the northern reefs. With a Hong Kong partner, the states of Kayangel and Ngarchelong set up holding pens. Fishing apparently did not start in earnest until September 1999, and after about one month of fishing between 1 and 2 mt of live and dead fish were sent by carrier ship to Hong Kong in what was described as an experimental shipment (Hoshina, pers. comm. 2000).

At least in Ngarchelong, the company bought both live and dead fish from or through the local fishing cooperative. Some of the dead fish may have been marketed in Koror. In Ngarchelong, the company was buying live fish at $2 per pound and dead fish at $1 per pound. In comparison, the local cooperative was buying fish at between $0.75 and $1.35 per pound (Hoshina 1999).[8]

[8] The harvest of sea turtles in Palau is restricted by season and size but there are no restrictions on export. The import of sea turtles, all species of which are listed on Appendix I under CITES, is prohibited into countries that are party to the convention, including the People's Republic of China. The export from Palau of tridacnid clams for commercial purposes was prohibited in May 1994, followed in May 1995 by a prohibition on exports for any purpose. The harvest of trochus in all states except Hatohobei (which includes Helen Reef) is limited to nationally declared open seasons. There are no restrictions on the export of trochus shells or meat.

Fishing for live fish in Palau seems to have ceased since the 1999 shipment from the northern reefs. Eddy Liu, one of the partners in that operation, complained about a lack of an adequate supply of fish from local fishermen, saying they were not fishing hard enough to make the operation viable. And at least in Ngarchelong, the cessation of fishing may have been due in part to pressure from the state government, which apparently opposed the fishery.

2.4 RELATED FISHERIES

Operations involved in Palau's ornamental and live food fish fisheries have also exported incidental species and have exported organisms for purposes other than the ornamental and food trades. Some operations exported chilled or frozen reef fish as well as live fish. The two northern reef operations, in fact, may have exported more dead fish than live fish. Palau Fishing Industry, which mostly exported food fish to Hong Kong, also exported small amounts of ornamental species to public aquaria in Japan and expressed interest in exporting live lobster. Both that operation and the most recent Helen Reef operation exported dried shark fin. One source put the export price at $25 per shark. It is not clear whether the sharks were targeted (for fins and/or feed) or taken incidental to fishing for groupers. Sea turtles, tridacnid clams, and trochus meat also appear to have been exported from Helen Reef together with live fish.

In the early 1990s Palau Aquatics exported invertebrates, including various species of sea slugs, to the U.S. National Cancer Institute for research purposes.

The expertise of the companies and personnel involved in catching and exporting live organisms make them attractive to secondary customers, including public aquaria and research institutions. The lines between "commercial," "educational," and "research" activities are blurry in the area of live fisheries, a fact that should be recognized in Palau's management regime. (Marine research and the ornamentals fishery are, in fact, regulated through the same set of regulations).

Also important with regard to management is the fact that once a trade link is established through a particular live fish exporting company, that company may at any time respond to occasionally unforeseen demand for any number of additional marine products.

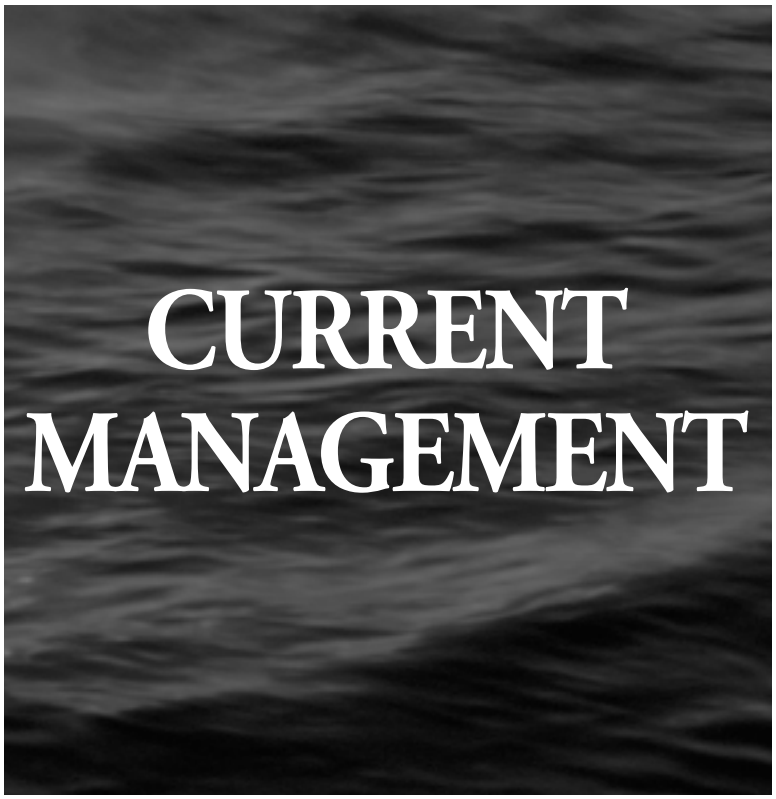
2.5 HISTORY SUMMARY

Table 13 summarizes the history of Palau's live reef fish fisheries, using the best available estimates of export volumes, as discussed in the previous sections.

Table 13. History of the live reef fisheries of Palau

Year	Ornamental Products			Food Fish		
	Number of Exporting Operations	Finfish Exports (1,000 pieces)	Invertebrate Exports (1,000 pieces)	Number of Exporting Operations	Exports (mt)	Location
1984	0	0	0	1	75	South
1985	0	0	0	1	75	South
1986	0	0	0	1	75	South
1987	0	0	0	1	75	South
1988	0	0	0	1	75	South
1989	0	0	0	1	50	Helen
1990	1	2	2	1	50	Helen
1991	1	100	0	0	0	
1992	1	200	20	0	0	
1993	1	100	20	1	0	Helen
1994	1	100	40	2	20+4	Helen+North
1995	1	100	40	2	20+4	Helen+North
1996	0	0	0	1	4	North
1997	0	0	0	0	0	
1998	1	0	3	0	0	
1999	1	10	2	1	2	North
2000	1	58	12	0	0	

- Some of the export estimates are very rough. Section 2 for further details, methods, and qualifications.
- The food fish figures include chilled and frozen reef fish shipped incidentally to live fish.
- Year-2000 estimates are full-year (partial-year data have been extrapolated through the whole year).
- These figures do not include exports made directly by PMDC, a government entity that exported cultured ornamental tridacnid clams to the U.S. market. Clams bought from the PMDC and exported by private companies are included.
- Exporting of ornamental products occurred prior to 1990, but apparently the volumes were low and the companies short-lived.
- On the locations, "South" refers to the southern lagoon, "Helen" refers to Helen Reef in the Southwest Islands, and "North" refers to the northern reefs.


CURRENT
MANAGEMENT

3. CURRENT MANAGEMENT

3.1 ORNAMENTALS

Following is a summary of restrictions and requirements that apply to the collection and export of marine ornamental products in Palau. Each set of provisions is followed by a qualitative assessment of the current level of enforcement and compliance.

3.1.1 National Laws

Marine Protection Act and Related Laws

The taking and export of marine organisms for aquarium purposes is regulated under the Marine Protection Act of 1994, enacted in May 1994, which mandated the Ministry of Resources and Development to promulgate regulations to govern the fishery. The "Regulations on the Collection of Marine Resources for Aquaria and Research" became effective in December 1994. A summary of their provisions follows (regulations enacted pursuant to 27 PNCA 1205-1206):[9]

- Any person collecting more than five pieces of "aquarium species" in a single day must be the *holder* of an *Aquarium Collecting Permit*. Permits fees are $100 per year.
- Any person exporting from Palau any "aquarium species" must be the *owner* of an *Aquarium Collecting Permit*.
- Each permit is issued in the names of both a permit *holder* and a permit *owner*.
- "Aquarium species" are those species of finfish and invertebrates designated as such on the *Regulated Marine Species Register* maintained by the Division of Marine Resources.
- *Aquarium Collecting Permits* are not transferable among *owners* but they are transferable among *holders.*
- Only Palauan citizens are eligible to obtain *Aquarium Collecting Permits* as permit *holders.* There are no such restrictions on permit *owners*.
- No more than 20 *Aquarium Collecting Permits* will be issued in any given year, and permit applications will be evaluated based on a set of criteria that include previous experience in the business, compliance with relevant laws, and contributions to marine life conservation efforts.
- An *Aquarium Collecting Permit* is valid only when endorsed by the proper authority of the State in which aquarium fish are being collected.
- Hard corals (including "live rock") and sponges may not be exported, but exemptions are provided for cultured specimens, specimens collected from permitted dredge sites, and specimens collected for permitted research purposes.
- The only fishing gears that may be used to collect aquarium species are barrier nets, drop nets, and hand nets.
- The national government may at any time further restrict the collection or export for aquarium purposes of any species of marine organism, such as through a ban or a daily or annual bag limit or quota.
- All exports of aquarium species are to be inspected by the national government.
- *Owners* of *Aquarium Collecting Permits* must report their catches and exports.
- Penalties for violation of the regulations range from a $250 fine for the first conviction up to a $10,000 fine and a one-year jail sentence for any conviction after a third conviction.

[9] The objectives used in formulating these regulations and what were then the most contentious issues in the fishery are discussed in Graham (1995).

Compliance The Division of Marine Resources (DMR) appears to be actively enforcing most provisions of the Regulations. Two collecting permits are currently held, both by employees of Belau Aquaculture, which is the owner of both permits. The permits specifically allow the use of compressed air. Although the regulations set collecting permit fees at $100 per year, Belau Aquaculture claims to be paying $300. The DMR routinely inspects exports prior to shipment and provides authorization for restricted species such as tridacnid clams and sponges, which must be certified as cultured. It is not clear whether the Bureau of Revenue, Customs and Taxation inspects the shipments, as required in the regulations. Belau Aquaculture provides quarterly sales reports to the DMR, but the reports appear not to include the level of detail required in the regulations, including catch, effort, and areas fished. One provision apparently not rigorously enforced is that only Palauans may collect. Although only Palauans currently hold permits, they are assisted by foreigners. Finally, the strict definition of "cultured" provided in the regulations is probably not being attained by some of the exported sponges and tridacnid clams-in order to meet the definition, organisms must be both certified as cultured by the DMR and in fact meet the criteria of being "bred in captivity," as defined under CITES, which is quite strict and would effectively require a nearly closed culture system.[10]

The export of any species of tridacnid clam, except cultured ones, is prohibited (27 PNCA 1204).

Compliance Inspection of exports and certification of clams as "cultured" appears to be routinely done by the DMR, but as described above, rigorous enforcement of the strict definition of "cultured" may not be done.

The use of compressed air while fishing, except as provided by regulation or permit issued by the Minister of Resources and Development, is prohibited (27 PNCA 1204).

Compliance The two currently held collecting permits include exemptions to the no-compressed-air provision.

The use of explosives or poisons for fishing is prohibited (24 PNCA 1302).

Compliance Although very little on-water patrolling is done by the national government, the use of explosives and poisons is fairly socially unacceptable. It probably only rarely occurs, and probably only in remote areas such as Helen Reef.

The Regulations on the Reporting and Labeling of Exports of Marine Resources, enacted under the Marine Protection Act and made effective in January 1996, require that exports of any marine products be declared in writing prior to export, including the net weight exported for each species and the product form (e.g., live or dead). It also requires containers that hold marine products to be labeled as such. It also requires that commercial exporters submit quarterly catch and effort reports to the DMR (regulations enacted pursuant to 27 PNCA 1206-1207).

Compliance Declarations appear to routinely be made by Belau Aquaculture and inspections appear to routinely be made by the DMR (although not required). Although the declaration requirements started to be enforced by the DMR in 1996, it is not yet able to provide regular summaries or analyses of those data or assessments of the level of compliance. It is not clear whether the labeling requirement is enforced or complied with. Belau Aquaculture submits quarterly sales reports to the DMR,

[10] The Marine Protection Act required the promulgation of regulations for procedures to certify species as cultured (27 PNCA 1207), but this has not yet been done. So while there is a clear definition of "cultured," procedures for certification have yet to be developed.

but the reports appear not to include the level of detail required in the regulations, including catch, effort, and areas fished.

Closed Areas

Fishing from April through July is prohibited at Ngerumekaol (24 PNCA 3101-3103) and fishing any time is prohibited in the Ngerukewid Islands Wildlife Preserve (24 PNCA 3001-3004).

Compliance Neither Ngerumekaol nor Ngerukewid would appear to offer anything special in terms of ornamentals, so it is likely that enforcement is not high priority and lack of compliance is not a problem.

Foreign Investment Act

No foreigner may carry on any business enterprise in Palau (i.e., have any interest in such an enterprise) without first obtaining a foreign investment approval certificate from the Foreign Investment Board (28 PNCA 103).

Certain business activities are reserved exclusively for Palauans and businesses completely owned by Palauans, including fishing for other than highly migratory species, tour guides, fishing guides, diving guides, water and land transportation services, and the wholesale and retail sale of goods. Mariculture is explicitly exempted from this provision (28 PNCA 105).

Compliance The enterprise of collecting and selling wild ornamental marine products is clearly reserved for businesses that are completely Palauan owned (so no foreign investment approval certificate would be needed). It appears that most or all the major collecting operations have been at least nominally owned by Palauans, but no research was done here to determine whether there has been any foreign interest in those businesses.

3.1.2 State and Traditional Laws

Some states, including Koror, have laws that require permits for fishing of certain types, for certain purposes, or by certain persons. Even in states without such laws, implicit or explicit permission from the state leadership, and perhaps payment of some fee, would likely be needed to engage in any "high profile" fishing-that is, intensive or regular fishing, particularly by foreigners.

Several states have fishing restrictions in certain areas. Only those in Koror, the main fishing grounds for the ornamentals fishery, are listed here.

Koror

Licenses are required to engage in commercial fishing (K3-42-90 and K4-68-95). The fee for net fishing is $120 per license per year, and a single license allows as many as 11 people to fish, if from a single boat.

Compliance Belau Aquaculture is currently permitted to collect by Koror State, to which it pays $500 per year. It appears that Koror is charging fees in addition to those required by statute through

some sort of contractual agreement with the company. Belau Aquaculture is also permitted by Airai State, to which it pays $100 per year.

Fishing with the use of explosives, poisons, compressed air, or nets with mesh sizes of less than 3 inches on any side of the hole is prohibited (K3-42-90 and K4-68-95).

Compliance Although the compressed air and net provisions have apparently been enforced in the past, resulting in confiscation of the fishing gear of previous collecting operations, current enforcement appears to be nonexistent. This is because the net restriction would effectively preclude collection of any ornamental finfishes and the compressed air restriction would preclude collection of deep-dwelling finfish and invertebrates.

Fishing is prohibited in the areas of Soft Coral Arch, Cemetery Reef, Ngkisaol, any marine lake (K6-95-99), Ngerukewid, Ngerumekaol (K6-101-99), and within one mile of the shores of Ngemelis and Dmasch islands (K3-42-90 and K4-68-95).

Compliance The active on-water patrolling program of the Koror State Rangers probably keeps compliance with these restrictions relatively high.

3.1.3 International Laws

Palau is not a party CITES, however, exports to countries that are party to the convention, including the United States, require compliance with those countries' applications of the convention. Products affected include tridacnid clams and stony corals, which are listed on Appendix II of the treaty, meaning that trade is allowed but export documentation and compliance with applicable laws of the exporting country are required. Live rock and sand are also affected, being composed partly of listed coral species, and soft corals are affected if they are attached to coralline substrate.

Compliance The U.S. requires in-lieu CITES documentation from the Palau government for Appendix II species and the U.S. Fish and Wildlife Service (USFWS) appears to actively enforce this provision at U.S. ports of entry. The Palau government, through authorization by the Bureau of Natural Resources and Development, appears to routinely provide such documentation for the sponges and tridacnid clams exported by Belau Aquaculture. Stony corals and live rock are not currently being exported.

The Lacey Act of the United States prohibits the import of fish or wildlife taken, possessed, transported, or sold in violation of any foreign law.

Compliance The USFWS appears to routinely enforce the Lacey Act at U.S. ports of entry. It has cooperated with Palauan authorities in the past with regard to the export of hard corals and live rock (in apparent violation of RPPL 3-61) and Belau Aquaculture reports that the USFWS routinely requires proper documentation (e.g., certification of sponges and tridacnid clams as cultured) for its shipments to the U.S.

3.2 FOOD FISH

There are no laws that apply specifically to the capture or export of live fish. Some species popular in the trade, however, are subject to seasonal and export restrictions, and there are certain gear and area restrictions and export requirements that are relevant. The important laws follow, with each set of provisions followed by a qualitative assessment of the current level of enforcement and compliance.

3.2.1 National Laws

Marine Protection Act and Related Laws

Fishing for, buying, or selling any of five species of grouper-*Epinephelus fuscoguttatus, E. polyphekadion, Plectropomus areolatus, P. laevis*, and *P. leopardus*-from April through July is prohibited (27 PNCA 1204).

The export of Napoleon wrasse, *Cheilinus undulatus*, is prohibited (27 PNCA 1204).

Fishing for, buying, or selling Napoleon wrasse, *Cheilinus undulatus,* less than 25 inches in length, is prohibited (27 PNCA 1204).

Compliance The restrictions in the Marine Protection Act against fishing have not been strictly enforced because little on-water enforcement occurs. But buying, selling, and export provisions have been fairly rigorously enforced by the Bureau of Natural Resources and Development since 1995 or 1996, and several cases have been settled with fines or gone to court. One inspection in 1995 of live fish bound for Hong Kong revealed a single *Cheilinus undulatus*, which was released by government officers without any enforcement action.

The use of compressed air while fishing, except as provided by regulation or permit issued by the Minister of Resources and Development, is prohibited (27 PNCA 1204).

Compliance Except to the small extent that cyanide may be used illegally, the fishery is limited to hook-and-line, so this provision is only marginally relevant.

The use of explosives or poisons for fishing is prohibited (24 PNCA 1302).

Compliance Although very little on-water patrolling is done by the national government, the use of explosives and poisons is fairly socially unacceptable. It probably only rarely occurs, and probably only in remote areas.

The Regulations on the "Reporting and Labeling of Exports of Marine Resources", enacted under the Marine Protection Act and made effective in January 1996, require that exports of any marine products-including the net weight exported for each species and the product form (e.g., live or dead)-be declared in writing prior to export. It also requires that containers holding marine products be labeled as such, and that commercial exporters submit quarterly catch and effort reports to the Division of Marine Resources (regulations enacted pursuant to 27 PNCA 1206-1207).

Compliance Although the declaration requirements started to be enforced by the DMR in 1996, it is not yet able to provide regular summaries or analyses of those data or assessments of the level of

compliance. It is not clear what portion of live food fish exports have been declared by the exporters, nor whether the labeling requirement is enforced or complied with. It does not appear that the catch and effort reporting requirements have ever been complied with by a live food fishing operation or that the DMR has attempted to enforce those requirements.

Foreign Fishing

Fishing for reef fish may not be done by foreign vessels (27 PNCA 161).

Compliance Fishing for live reef fish was undoubtedly done by foreign vessels in the late 1980s or early 1990s, but that appears not to have been a problem in the last few operations.

Closed Areas

Fishing from April through July is prohibited at Ngerumekaol (24 PNCA 3101-3103) and fishing any time is prohibited in the Ngerukewid Islands Wildlife Preserve (24 PNCA 3001-3004).

Compliance Live food fishing has not occurred in Koror's waters since the 1980s, so these closures are not particularly relevant right now. However, Ngerumekaol is an important aggregation site for groupers, and it is known to have been fished for live fish in the past. Being within the barrier reef, Ngerukewid is unlikely to have any special appeal to live fishing operations. Enforcement of these laws by the national government is quite weak but Koror State conducts fairly regular patrols to both these areas and is able to enforce its own similar laws in these two areas.

Foreign Investment Act

No foreigner may carry on any business enterprise in Palau (i.e., have any financial interest in such an enterprise) without first obtaining a foreign investment approval certificate from the Foreign Investment Board (28 PNCA 103).

Certain business activities are reserved exclusively for Palauans and businesses completely owned by Palauans. These activities and businesses include fishing for other than highly migratory species, tour guides, fishing guides, diving guides, water and land transportation services, and the wholesale and retail sale of goods. Mariculture is explicitly exempted from this provision (28 PNCA 105).

Compliance The enterprise of fishing for live food fish is clearly reserved for businesses that are completely Palauan owned (so no foreign investment approval certificate would be needed). While some or all of the operations that have been involved have been at least nominally owned by Palauans, all appear to have operated in partnership with foreign interests, arrangements that might have been in violation of this law. On the other hand, it would be fairly simple to configure a joint venture such that fishing itself were conducted by completely Palauan interests, leaving the foreign partners engaged only in the non-fishing aspects of the business. No research was done here to determine the degree of foreign interest in Palau's live food fishing operations or the degree of compliance with this provision.

3.2.2 State and Traditional Laws

Permits Required

Some states have laws that require permits for fishing of certain types, for certain purposes, or by certain persons. Even in states without such laws, implicit or explicit permission from the state leadership, and perhaps payment of some fee, would likely be needed to engage in any "high profile" fishing-that is, intensive or regular fishing, particularly by foreigners.

In Koror State, licenses are required to engage in commercial fishing (K3-42-90 and K4-68-95). The fee for hook-and-line fishing is $300 per license per year, and a single license allows as many as eleven people to fish, if from a single boat.

Compliance Hatohobei State apparently charged $1,500 per year plus $500 per shipment to the most recent Helen Reef operation. The permit arrangements for the other operations are not known, but clearly, permission by state leadership has been essential for continued access to fishing grounds.

Closed Areas

Several states have fishing restrictions in certain areas. Only those areas believed to be relevant to fishing for live food fish are listed here.

Koror State prohibits fishing year-round in the areas of Soft Coral Arch, Cemetery Reef, Ngkisaol, any marine lake (K6-95-99), Ngerukewid, Ngerumekaol (K6-101-99), and within one mile of the shores of Ngemelis and Dmasch islands (K3-42-90 and K4-68-95). Ngerumekaol is an important grouper spawning aggregation site. The Ngemelis closed area includes what were once important aggregation sites for groupers near German Channel and for groupers and Napoleon wrasse near Blue Corner.

Compliance No fishing for live food fish has been done in Koror since the 1980s. In any case, the active on-water patrolling program of the Koror State Rangers would probably keep compliance with these area restrictions relatively high.

Ngarchelong State prohibits entry and fishing year-round, at least until 2003, in an area surrounding Ebiil channel, an important spawning aggregation site for groupers and Napoleon wrasse (NSGPL No. 87).

Compliance Ebiil has been heavily fished in the last decade, probably including that done by the live reef fish operation that operated in the northern reefs in the mid 1990s. This law was only enacted in early 2000 (concurrent with a traditional bul), so it is not known how strong enforcement will be.

Kayangel State prohibits fishing at Ngeruangel atoll, with some exceptions (KYPL 7-02-96 and subsequent regulations).

Compliance Ngeruangel atoll includes good habitat for grouper and there are sites around the atoll identified by local fishermen as aggregation sites for various species of grouper, but it is not known how big the aggregations have been or how appealing the area might be to live fish operations. It is also not known if or how intensively the atoll was fished by the northern reef live fish operation in

the mid 1990s (before the closure). Its remoteness may make it difficult to transport live fish. Enforcement within the reserve has been fairly strong, with patrols by state officers reportedly made several times per week.

Ngeremlengui prohibits fishing year-round in two areas, Usas and Mecherong, and from June 1 to August 31 prohibits fishing in the channel Tewachel Mlengui, which is a known aggregation area for groupers (State Public Law No. 13-87).

Compliance The degree of recent enforcement and compliance with this law is unknown. Sources say that the channel was targeted in the 1980s, but perhaps before this law became effective in 1987.

A traditional bul declared by the chiefs of Ngarchelong and Kayangel in 1994 prohibits fishing from April through July in all eight major channels in the northern reef complex (Ngkesol, Ngebard, and Ngarael). At least two of these, Ebiil and Western Entrance, are known to be important spawning sites for groupers.

Compliance The degree of enforcement and compliance with this bul is unknown. Note that one of the channels, Ebiil, is now protected year-round under Ngarchelong State law.

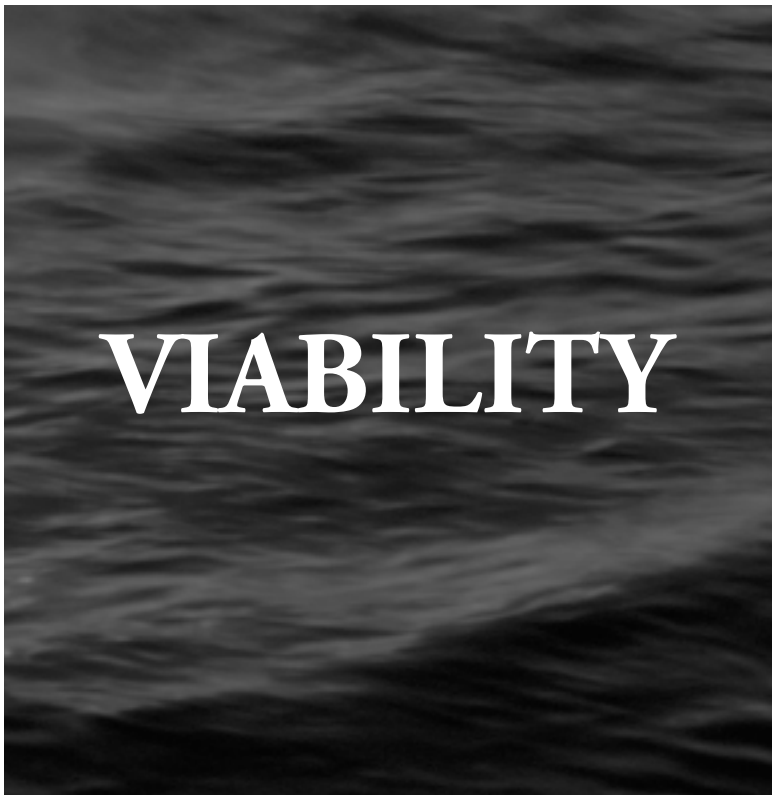
Method Restrictions

Koror State prohibits fishing with the use of explosives, poisons, compressed air, or nets with mesh sizes of less than 3 inches on any side of the hole (K3-42-90 and K4-68-95). Other states may have similar provisions.

Compliance Live food fishing for export has not occurred in Koror since the 1980s. The use of poisons and explosives has become quite socially unacceptable, and it is unlikely to have been done anywhere in Palau on a significant scale since the early 1990s.

3.2.3 International Laws

There are no marine fish species listed under CITES.


VIABILITY

4. VIABILITY

This section focuses on a fundamental question: Are live reef fisheries viable or good for Palau? A viable fishery would have certain attributes regarding efficiency and equity. In terms of efficiency, for example, one would generally seek a high level of economic rent, or net benefits, derived from the fishery and a sustained flow of benefits over time.[11] The bottom line on net benefits is dependent on the level of benefits and costs generated both within (i.e., profitability) and outside the industry itself. This includes impacts to benefits derived from alternative uses and values of the resource (e.g., external environmental costs and foreclosed opportunities). The stream of benefits and costs over time is, of course, important, and sustainability is generally desired.

The data required to accurately assess the net benefits of these fisheries, as well as the distribution of benefits, are not readily available. For example, the gross revenues and operating costs of virtually none of Palau's live reef fish operations can be estimated with enough precision to make meaningful estimates of profitability, let alone how benefits are distributed. Even more difficult would be determining whether a given level of net benefits or losses is sustainable-that is, making determinations of long-term yield and profitability from what have typically been short-lived operations. Finally, it is difficult to put a value on alternative uses of the resource and to assess the risks that live reef fisheries put on those uses and values. It is difficult, for example, to assess the value of a grouper spawning aggregation and risk of a live grouper fishery foreclosing that value.

Instead of attempting to do a thorough benefit-cost assessment of Palau's live reef fisheries, this section will address-mostly in qualitative terms-four attributes that collectively provide a useful description of viability:

1. profitability of the fisheries and specific operations
2. productivity of the fisheries resources-towards the question of sustainability
3. competition, or impacts of the fishery on alternative uses and values
4. distribution of benefits among interested parties

The last attribute-distribution of benefits-can be especially revealing and important for management. From a national policy perspective, for example, it is critical that Palau earns a fair return on its resources vis-à-vis foreign interests in the industry. It is also important to recognize that regardless of the profitability of an enterprise as a whole, any single stakeholder not pleased with his share of the returns will have an interest in closing the enterprise.

The fact that most live reef fish operations in Palau have been short-lived is itself very informative, and this discussion will focus on identifying the reasons for the off-and-on nature of the industry. In the process, some of the most important issues for management will be identified, serving as an introduction to Section 5, "Prospects for Management."

[11] Economic rent essentially means net economic benefit, but in a broader sense than just "profits," as it describes the net benefits to society as a whole.

4.1 ORNAMENTALS

4.1.1 Profitability

One important but inconclusive clue regarding profitability is that no ornamental collecting business in Palau has lasted longer than four years. Chibana said of Palau Biotech that its profits came primarily from hard corals and live rock. In 1994, when the export of those products was prohibited by national law, the operation ceased to be profitable and the company folded. According to the owners of Belau Aquaculture, it is currently operating just about at the operation's break-even point of $2,500 in sales per week, but the company has plans to expand significantly.

4.1.2 Resource Productivity

Concerns about several types of ecological impacts of ornamental collecting appear regularly in the literature. These include: 1) direct degradation of habitat, such as from poisoning, physical destruction of corals, and the collection of hard corals and live rock; 2) impacts to target populations from removal of organisms; and 3) impacts to reef communities from removal of organisms (e.g., loss of herbivorous fishes resulting in increased algal cover). Another common concern is that these impacts are exacerbated due to excessive post-harvest mortality.

In Palau, as in several other countries and locales, the use of poisons while fishing is prohibited. As far as is known, since the industry started there have been no enforcement actions by either the national or state governments that involved the illegal use of sodium cyanide or other poisons.[12] On the other hand, the national and state governments engage in very little direct observation of collecting operations. Although the DMR and Koror State occasionally installed observers on collecting boats in the early years of the industry, they have not done so again for at least five years. Sharron of Belau Aquaculture said that he believes that sodium cyanide has never been used to collect ornamental fish in Palau.

Whether or not the export of hard corals and live rock should be allowed has, with the growing demand for these products in home aquaria, become an increasingly contentious issue in many source nations. Although like fishes, corals and the rock they produce are renewable living resources, particular concern has been paid to corals because of their fundamental role in building reef and providing habitat. Under CITES, all scleractinian corals (and thus live rock) are listed as Appendix II species, thereby regulating but not prohibiting their trade. Restrictions on harvest and export have become increasingly strict in the United States and many of its local jurisdictions, including Florida, Hawaii, Guam, and the Northern Mariana Islands. The issue was one of the most contentious ones in Palau's process of formulating its ornamental fishery regulations in 1994. The industry argued that corals and rock could be harvested sustainably and with little impact, but the government adopted a more cautious approach and ultimately prohibited the export of hard corals and live rock (with some exceptions).[13]

[12] Koror State has had in recent years a more active on-water enforcement program than the national government. Most or all of its enforcement actions with collectors appear to have been related to permit requirements and the illegal use of compressed air while collecting.

[13] The industry pointed out that the environmental impacts of live rock harvesting, which can be very selective, would certainly be less than those of Palau's widespread (and legal) coral dredging operations (which harvest rock for construction material). It also argued that live rock (exported at US$1 to $2 per pound) constituted a better use of coral rock than did construction material (sold locally for less than $0.01 per pound). In response to these arguments, the government provided export exemptions for hard corals or live rock taken incidentally to permitted dredging operations.

Since the export of hard corals and live rock was prohibited in late 1994, the DMR has monitored exports of marine products at the airport-particularly ornamentals-fairly rigorously. This has been especially true in the last few years, so it seems reasonable to believe that compliance with these provisions has been good. Since Palau Biotech stopped operations in 1996, there has apparently been no further pressure from the industry or the public to relax the restrictions.

Even if poisons are not used and the substrate itself is not harvested, collecting can still cause damage to the substrate. Sharron acknowledged that accidental breakage of corals during collecting does occur. He also said that Belau Aquaculture enforces an in-house rule on employees against intentional breakage of corals, and that the $100 penalty has been imposed once. He also noted that areas with highly structured live coral, particularly branching coral, make poor collecting areas because of the damage caused to the fine monofilament nets that are used.

The impacts on fish and invertebrate populations of removing the organisms have been widely debated (see Pyle 1993). Some studies have found no impact on target populations from collecting, others have been inconclusive, and some have detected differences. But even in one case in Hawaii where differences between fished and control sites were found for several target species, the most extreme difference in abundance was only 57 percent (Tissot 1999).[14] The same study found no differences between the fished and unfished areas in terms of bleaching, broken coral, coral cover, or macro-algal cover. Regarding finfishes, Pyle (1993:9) concluded that:

> "Those of us who have carefully examined the problem and have many years of experience observing coral reefs and the effects of aquarium fish collecting (including myself, Dr. Randall, and others) feel very confident in concluding that aquarium fish collectors using non-destructive techniques (such as nets) do not measurably impact coral reef fish communities. From an ecological perspective, aquarium fish collectors have virtually no impact when compared to the impact caused by natural perturbations."

Being typically small species, ornamental fishes generally have higher reproductive rates than larger food species, enabling more surplus production. The principals of Belau Aquaculture said that their observations of the dynamics of some of their target species-such as their top seller, blue damselfish (Chrysiptera cyanea)-in localized areas revealed what they considered to be a high replenishment rate, giving them the ability to continually collect from a relatively small number of favorite fishing areas.[15]

Most governments in exporting countries have exerted little control over fish collecting and exporting operations, often relying on guidelines rather than rules (e.g., Fiji). Some require collecting and/or exporting permits. Others have limited the number of exporting companies or collectors (e.g., Palau). Some countries have instituted or considered quotas on the total number of fish exported (e.g., Maldives, Tonga). At least one, the Maldives, has instituted species-specific quotas, based on stock assessments and surplus production estimates (Edwards and Shepherd 1992).

There has been increased effort on the part of importing countries to control what is imported through certification and labeling mechanisms, particularly with regard to fishes caught with sodi-

[14] Assuming this meant that biomass in the fished area was 43 percent of that in the un-fished area, this is consistent with expectations in the case where the population was being maximally exploited (assuming that biomass at maximum sustainable yield is roughly one half of un-fished biomass).

[15] Such replenishment could be from both immigration and recruitment; Pyle (1993) cited studies that suggest that recruitment would be the more important mechanism, particularly for most aquarium fish species, which have small territories and tend not to emigrate.

um cyanide and those not "suitable for a captive life" (e.g., Wood 1992:3). The latter is concerned with the waste (and added pressure on the resource) that results from fishes that are captured but die before or soon after purchase by the consumer. Because it is the consumers that should determine which species are suitable for captive life, it is unclear how any such species would ever enter the market. In other words, it is not clear that this is really a problem worthy of government intervention. In any case, to the extent that it is a problem and that it is caused by an inability of consumers to get the information they need (clearly a problem for cyanide-caught fish but not clearly a problem for suitability-for-captive-life), it should be adequately addressed by the ongoing industry initiative led by the Marine Aquarium Council. The initiative seeks to improve the flow of information to consumers through certification mechanisms it (see Section 5.7 for more).

Given the relatively small size of the industry in Palau, the lack of destructive collecting techniques, and the widely held view among experts that the ecological effects of collecting ornamental organisms (excepting hard corals and live rock) are, in general, small, it appears that there is no immediate cause for concern about the ecological impacts of the industry. However, two areas to keep an eye on, especially if and when the industry expands, are the degree of damage made to corals in the process of collecting and the impacts on rare and endemic species.

Assessing the degree of damage made to corals in the process of collecting would require occasional in-water surveillance on the part of the government. Evaluating impacts on rare and endemic species could be accomplished through regular consultation with principals in the local industry; they could, for example, share their observations of changes they observe in the water and in their catch rates. As well, their catch data could be tracked. Since the government already collects all the relevant data, with very little extra effort a simple analytical routine could be constructed to identify radical changes in collection rates of particular species. Finally, probably the simplest and most effective way to get a handle on the industry's impacts on rare and endemic species populations would be through monitoring *where* the collecting takes place. If collecting continues to focus on the same few areas through time, it would be indicative of adequate surplus production rates in those areas. If, on the other hand, collecting effort is observed to constantly move from one area to another (as is often observed in live food fish operations), it would be indicative of collecting having a substantial impact on local abundance.

4.1.3 Competition with Other Uses

In Palau the ornamentals fishery has had a mixed reputation among government leaders and the public. The Fourth Olbiil Era Kelulau (national congress) considered outlawing the industry altogether, but instead left it to the Ministry of Resources and Development to enact regulations to control the industry. This resulted in the *Regulations on the Collection of Marine Resources for Aquaria and Research*. The state of Koror, where most collecting has taken place, has been cautious about permitting collecting in its waters, thus effectively barring collection for much of the last ten years. It still has two prohibitions that effectively preclude collecting ornamental finfish: neither the use of small-meshed nets nor compressed air while fishing are permitted. (At the same time, however, the state of Koror has issued permits to collectors.)

It is unclear what the most important public concerns with the industry have been. They have probably included a mix of concerns about impacts to target organisms, food fish species, habitat, and

discontentment with those doing the collecting (mostly foreigners). There has also been concern that the industry effectively competes with the tourism industry by removing the organisms and/or destroying the habitat that supports that industry.

The ornamentals industry, at its current scale and with its current practices, probably competes with the tourism industry to an insignificant degree, especially with the latter being restricted to relatively few and discrete areas. Koror State law already prohibits fishing in many of the most visited areas, and further separation could easily be done through conditions on the collecting permits. The degree of competition with the food fishery is similarly minimal. Very few food species are caught by the fishery for ornamentals (*Naso literatus* being one), and it is unlikely that the fishery is having strong ecological impacts that are affecting populations of food fish species. Other areas of possible competition are with non-direct uses, such as the value of biodiversity. As described above, it appears unlikely that the fishery is having significant ecological impacts, but again, that should be the focus of monitoring if and when the fishery expands-that is, the government should examine the fishery's impacts on rare and endemic species and its physical impacts on corals.

4.1.4 Distribution of Benefits

This section highlights the perspectives of some of the players in the fishery. It is worth noting that unlike the live food fish fishery, which has had a relatively high degree of foreign interest, the ornamental fishery has always been dominated, at least in ownership, by Palauans. On the other hand, the collectors in the ornamental fishery have always been dominated by foreigners, in contrast with the live food fishery, in which both foreigners and Palauans have been important participants.

Benefits to Local Fishermen

While Palauans have typically had high degrees of ownership in ornamental operations, employment has been dominated by foreigners, as in many sectors of the Palauan economy. Collecting and managerial positions have been mostly held by foreigners. The 1994 aquaria regulations sought to replace foreign collectors with Palauans by prohibiting collecting by foreigners starting in 1997. Such a transition has not fully taken place. Palauans have been employed as assistants to the Filipino collectors (but nominally the other way around), as boat operators, and as workers at the holding and packing facilities.

As in most service sectors in Palau, the labor costs for foreign workers are less than for Palauans. And just as important, according to the principals of Belau Aquaculture, the collecting efficiency of their Filipino employees is much greater than that of any available Palauans. They said that the goal of getting Palauans trained to the point that they could compete with Filipinos is a distant one, and they offered 10 years as a reasonable target for even a possibility of seeing it happen. The Chief of the Division of Marine Resources agreed and said that he is considering having the regulations changed so that non-Palauans would be allowed to collect ornamentals.[16] He said that he would want the change to be accompanied by a requirement that the foreign collectors be accompanied by Palauans. This would not be in order to train the Palauans. Rather, it would be so that the Palauans could ensure that the foreigners do not break any laws or take things that they should not take. In

[16] The Palauan-only restriction was established in the December 1994 aquaria regulations, but with a grace period of two years-until January 1, 1997-before the restriction would take effect. Belau Aquaculture currently has two permitted Palauan collectors, who are accompanied by Filipino assistants.

any of these cases, some employment opportunities for Palauans would be guaranteed in any collecting operation.

The principals of Belau Aquaculture noted that while Palauans may never be able to compete with foreigners as fish collectors, they could become effective collectors of invertebrates and experts at mariculture. Their company, for example, is planning to step up farming of hard corals and other organisms.

It is not clear to what degree the occupation of collector or mariculturist appeals to Palauans. Without restrictions against foreigners in these occupations, it is unlikely Palauans could compete anytime soon. Even with such restrictions, the local labor pool is relatively small and competition with the public sector is great.

Benefits to Local Communities

The exporting operations have always been based in Koror and most of the collecting has taken place in Koror. The operations generate some local economic activity, such as through its salaries paid and local purchase of supplies and services. The state of Koror collects revenue through lease of the land on which the facilities are based and through fishing permits. Belau Aquaculture is currently paying Koror $500 per year to collect, presumably through some sort of contractual agreement, since Koror State law provides for a charge of only $120 per year for commercial net fishing (for up to 11 people fishing from a single boat). Belau Aquaculture also pays $100 per year to Airai State.

Benefits to Local Businesses

Local businesses are essentially the only businesses in terms of the collecting and export stages of the trade, so the above section on profitability covers benefits to local businesses.

Benefits to the Nation

In addition to the indirect benefits that can be generated through employment, local purchase of supplies and services, and local spending of company profits (none of which are assessed here), Palau as a whole can directly benefit from the industry through the transfer of economic rent to the national treasury. The main mechanisms for doing so are the gross revenue tax and the income tax. The gross revenue tax is 4 percent of a business' gross revenues (less 100 percent of salaries paid to Palauans and 50 percent of salaries paid to foreigners). The personal income tax varies from 6 to 12 percent of income.

Very roughly, if we assume that Belau Aquaculture is currently grossing about $250,000 per year and paying about $100,000 in salaries, the gross revenue and income taxes should generate about $16,000 per year. Other taxes, including the import tax, should generate a bit more, for a total of perhaps $20,000.[17] This constitutes about one-tenth of 1 percent of the government's total revenue from domestic sources. Tax revenues from the industry were presumably substantially greater in the early 1990s when export volumes were greater than they are now.

[17] No research was done to determine the actual amount collected by the government. There are other support services that also pay taxes to the government, but the most important one, the transport by air, was accounted for because the gross revenue given for Belau Aquaculture included revenue from freight charges. In fact, it is possible that both Belau Aquaculture and the freight carrier are liable for gross revenue tax on the revenue from freight because they both collect the revenue (see discussion in Section 6.10).

The industry brings other benefits to the national economy, including providing an additional sector to what is a fairly narrow economy (tourism and funds from the Compact of Free Association with the US being the most important sectors) and an additional source of foreign exchange.

Benefits Outside Palau

Since Belau Aquaculture is locally owned and operated, any benefits generated by it spend a relatively long time in the local economy. As with most sectors in Palau, sources of "leakage" include remittances by foreign workers and expenditures on imported supplies and services.

The industry in Palau is, of course, linked with other elements in the U.S., including wholesalers, retailers, and consumers. The benefits generated in each of those sectors are not addressed here.

4.1.5 Summary

There appears to be no practical limit on the demand for the types of ornamental products that Palau can provide. There also does not yet appear to be any practical limitations on the potential supply of those products-that is, on the productivity of the resource. The most important constraints on the industry appear to be the cost of freight (which is high compared to all other sources), the availability of cargo space (which competes with the sashimi tuna industry), and the costs of most inputs to production (which are high compared to Asian sources). Secondarily, government regulations constrain the potential profitability of the industry by prohibiting the use of relatively inexpensive and productive foreign labor, by prohibiting the export of what could be profitable products (including wild hard corals and live rock), and by prohibiting certain collecting methods (in Koror State especially). There is consensus both within and outside the industry that the restrictions on species and methods are justified in terms of protecting valuable resources. There is not a consensus on whether the Palauan-only restriction (an issue broader than fisheries management) is justified, and it clearly constrains the viability of the industry, at least in terms of collecting finfishes. Still, the current operation appears to be viable, in part through Palau's comparative advantage with certain species and the reputation of its product being hand-caught.

4.2 FOOD FISH

4.2.1 Profitability

The typically brief life spans of the live food fish operations, particularly the latest one in the northern reefs, suggesting poor profitability-or at least poor sustained profitability. The longest running operation lasted just three years.

Prices alone do not tell us much about profitability but they can help describe the gross value of the fishery and make crude comparisons with other uses of the resource.

Ex-fisher prices for live fish, at least for the northern reef operations, have been about $2 per pound ($4.40/kg). Export prices, at least for the most recent Helen Reef operation, appear to have been around $4 per pound ($9/kg). Ex-fisher prices for chilled reef fish have typically been a little less

than $1 per pound in recent years. Export values of chilled or frozen reef fish sent to Guam or Saipan, Palau's most important markets, are not known, but they have probably been less than twice the ex-fisher value. Wholesale values in Hong Kong for live fish appear to have averaged at least two to three times the export value. Retail prices in Hong Kong are roughly twice the wholesale value (from data in Lau and Parry-Jones 1999).

In describing the Helen Reef operation in 1994, Johannes and Riepen (1995:47) said that "the economic viability of this operation is not considered secure" due to the long time (about two months) required to collect five tons of fish-the minimum required to make a shipment cost-effective. They also cite the difficulties in catching operations-including recruitment and retention of fishermen. The operation stopped about a year later.

As previously stated, Liu said the main constraint was the need for a large and consistent supply of fish from local fishermen.[18]

Olikong reported that his northern reef operation, which shipped by air, had a break-even export volume of about 200 pounds per week (per flight), and that he tried to maintain exports at about that level. Air cargo rates from Palau to Hong Kong were quite high at $3.74 per kilogram and there were no direct flights between Palau and Hong Kong. Olikong said the main constraint to his business was the tortuous flight route-the fish having to be flown through and transferred in Guam, resulting in high mortality rates. He said that he would probably start the business again if there were a direct flight to Hong Kong. He also said that there were potentially lucrative markets for live reef fish in Manila and Taipei, but that he had not tried either. Palau has direct flights to both those cities (see Appendix 1 for more information on cargo rates from Koror).

These perspectives illustrate the fundamentally different constraints to profitability between operations that ship by sea and those that ship by air. By-sea operations require minimum shipment sizes to make them cost-effective.[19] (On the other hand, Chan (2000b) noted that because of the currently depressed demand in Hong Kong, such large shipments make it difficult for the fish to sell quickly.) Because of post-harvest mortality and the substantial feed requirements of the fish while being held, fishing costs increase substantially relative to revenues as the holding time increases, with impacts both on the resource and on profitability.

The effect of holding time, or "fishing period," on profitability is illustrated in Figure 2, which shows revenues to the exporter net of the costs of catching the fish (or buying them from fishermen), assuming the exporter bears the cost of all fish caught. This simple model assumes that the daily catch rate of all species combined is constant through time (e.g., fishing effort and catch-per-unit-effort (CPUE) are constant, and CPUE is the same for target fishing as for feed fishing). It is assumed that feed requirements are first met by dead target species, then by other species, whether they are caught incidentally to target species or specifically for feed. It is also assumed that feed requirements are met before catching new target species, or, put another way, that the fishermen are able to, and do, avoid catching target species when feed fish are needed. Based on anecdotal infor-

[18] Twelve fishermen from Ollei provided the company with about 0.5 mt of live fish and 1.0 mt of dead fish during one month of fishing, in September 1999 (Hoshina 1999). After combining these with the catch from Kayangel, the shipment of live fish totaled no more than 1 or 2 mt.

[19] Johannes and Riepen (1995) cited Hong Kong sources that said 10 mt was the minimum shipment size from the Pacific Islands and that 15 mt would be ideal. Donnelly *et al.* (2000) reported 15 mt to be ideal, with a maximum of 30 mt. Chan (2000a) said that the large fish carriers working the more distant Pacific Islands required 20 mt to be cost-effective. Patris reported that 5 mt was the minimum shipment size for his Helen Reef operation.

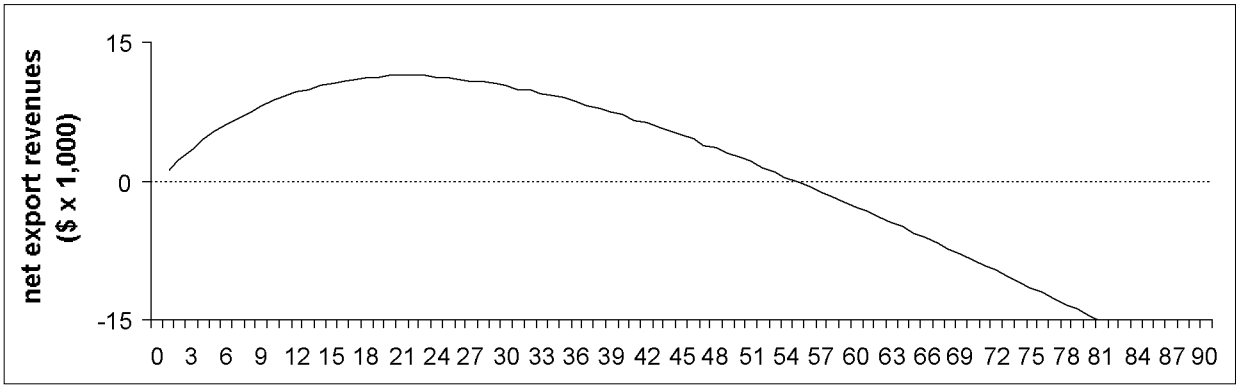
mation, particularly on the latest Helen Reef operation, the following rates appear to be typical and will be used in this illustration:

mortality rate	=	2 % per day, by weight
feed rate	=	5 % per day, by weight

Given these assumptions, the basic shape of the curve will be one that initially increases as the fishing period increases, then decreases after reaching a peak. The exact shape and scale of the curve will be determined by the daily catch rate of all species combined and the prices and operating costs to the exporter. For the illustration in Figure 2, the following catch rate, price, and costs are assumed. These are the costs to the exporter and price paid to the exporter (or export value, if not actually sold upon export). Not accounted for are fixed costs and other running costs associated with holding the fish.

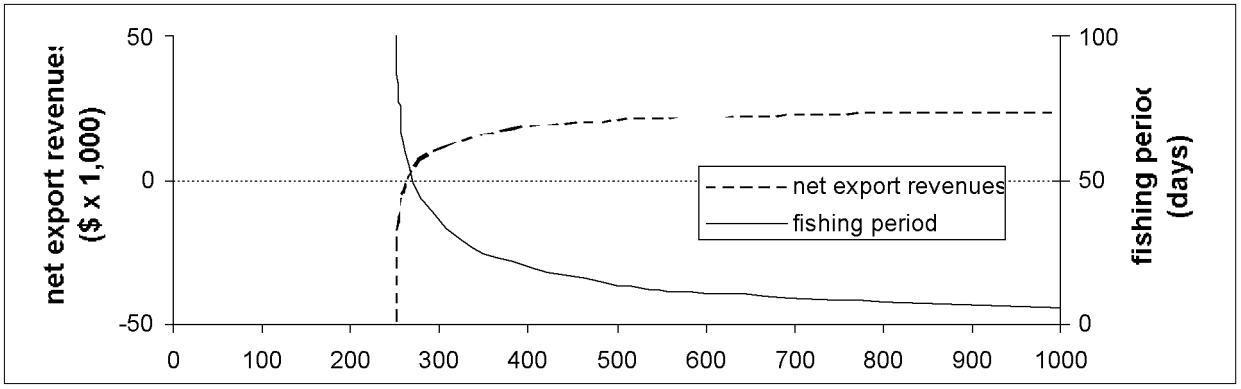
catch rate, all species	=	250 kg per day
price, target species	=	$10 per kg
cost, target species	=	$ 5 per kg
cost, other species	=	$ 1 per kg

Figure 2. Net export revenues, by fishing period



Fishing period is a function of the minimum shipment size and fishing intensity, so fishing intensity is a very important factor in terms of profitability. The faster the carrier ship is filled, the fewer the losses to mortality and feed and the greater the potential profits. Figure 3 illustrates this relationship using the same assumptions used previously, plus a (minimum) shipment size of 5 mt. Given a (constant) daily catch rate, there is a maximum attainable shipment size, equal to the catch rate divided by the greater of the feed rate and the mortality rate. In this example, at 250 kg caught per day, the maximum attainable shipment size is 250 kg/day divided by 5 percent/day, or 5 mt. Thus, given a minimum shipment size of 5 mt, any catch rate less than 250 kg/day will result in the shipment size never being attained, as illustrated in Figure 3. Unless the catch rate is substantially above that critical daily catch rate, profitability can be seriously constrained, so unless fishermen can be mobilized to fish fast and hard enough to get a shipment out quickly, he prospects for profitability can be bleak.

Figure 3. Net export revenues, by fishing intensity



Clearly, the brief holding periods associated with shipping by air are greatly advantageous. But even the northern reef operation that shipped by air had problems with the amount and consistency of supply from fishermen. In 2000, Olikong said that the fish stocks were simply not great enough to sustain his business, but given the modest size of the operation, that seems unlikely. A problem he cited in 1994, that he was having trouble getting the fishermen to provide him with enough fish, seems more plausible.

Brief holding periods also have the advantage of decreased risk of massive loss, whether it be from theft, sharks, water quality, or disease, and probably higher quality fish, as well. At least in Palau's case, however, shipping by air has the disadvantage of greater mortality rates during shipping, discussed further in the next section.

4.2.2 Resource Productivity

Impacts of Fishing

Concerns about the ecological effects of the live food fishery can be divided into its impacts on the reef itself-that is, "destructive" impacts-and impacts on the target fish populations-that is, the effects of removing fish. In Palau, cyanide was clearly used intensively at Helen Reef around 1990. Since then, it appears not to have been used much, if at all, either at Helen Reef or in the main islands, and hand-lining has been virtually the only method used. In terms of overfishing, problems could include merely fishing the stocks down to less-than-optimal levels, but not irreversibly so (economic overfishing). Or, they could include fishing the stocks down to the point that largely irreversible detrimental changes occur, either to target species or to other species (ecological overfishing). Impacts to spawning aggregations have increasingly become a concern throughout the tropics as evidence mounts that many grouper aggregations have been fished to the point of irreversible disappearance. In Palau, aggregations of several species of groupers have virtually disappeared from several sites, including one, Denges, that was fished down by the live food fish operation in the late 1980s (see Johannes *et al.* 1999).

Based on scientists' very limited knowledge of reef fish spawning aggregations, the overall value of a spawning aggregation to a species reproductive strategy is difficult to gauge. A population as a whole may not experience impacts in proportion to the impacts on one or more of its aggregations. It might, for example, shift to spawning in smaller groups. Or, aggregations may be critical elements

in the reproductive systems of populations, and to the extent that an aggregation is vulnerable to fishing, so is the population. Given the uncertainty concerning the degree of importance of spawning aggregations, it is reasonable to gauge our impacts to fish stocks (as well as our "success" in managing them) not only in terms of abundance and yields, but in terms of the persistence of spawning aggregations, as well. Put another way, placing value on spawning aggregations per se-not just on the populations they represent-and managing them accordingly is a precautionary and appropriate approach.

Yields

Palau's live reef food fishery has always been fairly small compared to its total reef fishery. At the live food fishery's peak of about 25 mt per year, the exported catch comprised about 1 percent of the country's total annual reef fish catch (roughly 2,000 mt).[20] Including mortality and fish used as feed (examined further below), the fraction was probably about 3 percent.

As a rough exercise, let us suppose that Palau's recent total reef fish yield of 2,000 mt per year is both sustainable and a desirable rate of sustained production, and further, that the portion marketable in the live food fish trade (e.g., only serranids, or groupers) is 8 percent,[21] or 160 mt. Then, at its peak, and including non-exported mortalities, the live reef food fishery comprised perhaps 20 percent of the "available" catch of groupers.

Most of the operations, however, were fairly localized, with relatively high, if not sustained, yields from discrete areas. The most recent Helen Reef operation, with its well-defined fishing grounds and apparent lack of other reef fishing during the life of the operation, provides the best case study. The operation exported between 30 and 50 mt of what was predominantly groupers over a period of about two years. Using the simple model described in the previous section, the actual catches of both target species and other species can be roughly estimated. The same assumptions of mortality rate (2%/day) and feed rate (5%/day) will be used, along with the assumption that all shipment sizes were 5 mt. (In fact, they varied between 4 and 7 mt.). Two annual shipment rates that bracket what appears to be the likely range of actual shipments will be analyzed: 15 and 30 mt. At 15 mt/year, it will be assumed, based partially on information from Patris, the local partner, that shipments were made after 70 days of fishing and that three shipments were made per year (210 days of fishing per year). At 30 mt/year, it will be assumed that shipments were made after 35 days of fishing, and that six shipments were made per year (210 days of fishing per year). The resulting catch estimates are shown in Table 14.

Table 14. Estimated catches at Helen Reef, by annual shipment amount

	15 mt/year	30 mt/year
Catch, target species (mt/yr)	31	43
Catch, other species (mt/yr)	23	20
Catch, all species (mt/yr)	54	63
Feed consumed (mt/yr)	39	33
Catch rate, all species (kg/day)	257	300
Target catch/target shipped	2.0	1.4
All catch/target shipped	3.6	2.1

• See text for a description of the reliability of these estimates.

[20] PCS (2000) estimated annual reef fish landings for the main island of Palau of between 1,500 and 2,000 mt from 1989 through 1998.

[21] Groupers fairly consistently comprised about 9 percent of sales at Koror's most important reef fish outlet from 1976 through 1990, but dropped to about 6 percent from 1991 through 1993 (DMR, no date).

It can be seen that there are substantial differences between the two scenarios in fish lost to feed and mortality and consequently, in efficiency, as expressed in the ratios in the last two rows of the table. These ratios are dependent on the fishing periods assumed for each scenario (70 and 35 days)-the briefer the period (given the same shipment size per period), the more efficient the operation because of proportionately lower losses to mortality and feed requirements. Between these two scenarios, there was a two-fold difference in the amount of fish shipped but only a small difference of 9 mt in total catch.

It should be emphasized that these results are based on a number of assumptions, some with relatively poor levels of reliability. These estimates can provide a rough gauge of the level of harvest that occurred at Helen Reef. The primary intent, however, is to illustrate that the relationship between the amount of fish shipped and the amount caught is dependent on a number of factors. These include mortality rate, feed rate, shipment size, and fishing intensity. Small changes in some of those factors can have large impacts on the relationship between fish shipped and fish caught, and consequently on profitability and on fish stocks.

The catches estimated above for Helen Reef can be translated into yields per unit area, as shown in Table 15. These estimates are based on Helen Reef having a total reef-lagoon area of 160 km^2 and a rocky reef area of 60 km^2. Not all the non-target species catch was comprised of reef species, as Patris reported that trolling was sometimes done to catch feed fish. It will be assumed (with little basis) that half the non-target species catch was comprised of reef-associated species. Further, it will be assumed that no other reef fishing went on at Helen Reef during the two-year life of the operation. Finally, it will be assumed that all target species were groupers.

Table 15. Estimated yields from Helen Reef, by annual shipment amount

(mt/km^2-yr)	15 mt/year		30 mt/year	
	Grouper	Reef fish	Grouper	Reef Fish
Total reef-lagoon area	0.19	0.27	0.27	0.33
Rocky reef area only	0.52	0.71	0.72	0.88

• See text for a description of the reliability of these estimates.

Little is known about the potential production of the grouper and reef stocks of Helen Reef specifically, but yields observed in other areas can help put the above estimates in perspective. A wide range of yields has been reported from tropical reef fisheries around the world. Reported yields depend not only on fishing effort and the productivity of the reef, but also on how they are measured-such as which species are considered "reef" species and which substrate types and what depth range are considered "reef."

One compilation of estimates included yields that ranged from 0.1 to 44 mt/km^2-yr (Dalzell 1996). Dalzell (*ibid*:189) concluded that "...yields well in excess of 5 t km^2 $year^{-1}$ are possible, particularly from reefs in South East Asia and the Pacific." The reef fish yield from Palau's main islands has been in the range of 1 to 1.3 mt/km^2-yr (total reef-lagoon-mangrove area), or 3 to 4 mt/km^2-yr (rocky reef area only), during the last 10 years.[22] If we take 1.5 mt/km^2-yr (total reef-lagoon-mangrove area) to be a "safe yield" (SY) from a typical reef system, then the total reef fish catch estimated above for

[22] Derived from a total catch of 1,500 to 2,000 mt/year, a total reef-lagoon-mangrove area of 1,500 km^2, and a rocky reef area of 500 km^2.

Helen Reef comprised 18 to 22 percent of SY.[23] Grouper catches have typically comprised about 8 percent of commercial catches in Palau. Eight percent of our reef fish SY of 1.5 mt/km^2-yr would be 0.12 mt/km^2-yr, so the grouper catch estimated above for Helen Reef comprised 160 to 225 percent of SY for groupers.

Anecdotal information suggests that catch rates declined markedly during the two years of fishing at Helen Reef, as would be expected given that the operation brought a dramatic increase in fishing effort (increasing effort would always be expected to result in decreasing catch rates).[24] Whether or not grouper or other fish stocks were fished down to undesirable levels (e.g., such that SY could no longer be produced) is not clear. It is also not known whether the operation reached a point of ecological overfishing. It is apparent that spawning aggregations were targeted, but the effects on the aggregations are unknown.[25]

It is clear that the interval between shipments, which is a function of fishing effort, is a critical factor with regard to efficiency. Under the assumptions made above, and considering the two scenarios as extremes in the possible range of shipment sizes, the amount of fish harvest needed to ship 1 kg of live grouper from Helen Reef would be between 2 and 4 kg. Assuming additional mortality during shipment-say, 40 percent (see below)-the total catch needed to deliver 1 kg to Hong Kong would be between 3 and 6 kg.[26]

In contrast with the Helen Reef operation, the northern reef operation had the advantage of being able to ship small amounts by air, which it did every one or two weeks. The advantage in terms of the amount of fish catch needed to ship a given amount of live fish is illustrated in Table 16, which shows several ratios that reflect some aspects of efficiency for each of five example fishing periods, ranging from 7 to 120 days.

Table 16. Ratios of total catch to shipment and delivery sizes, by fishing period

	7 days	30 days	60 days	90 days	120 days
Target catch/target shipped	1.1	1.4	1.9	2.4	3.0
All catch/target shipped	1.2	1.9	3.1	4.5	6.0
All catch/target delivered	1.9	3.2	5.2	7.6	10.0

• All ratios assume mortality of 2%/day, feed rate of 5%/day, and constant daily catch of all species combined.
• Third ratio assumes 40 percent mortality during transport to destination.

This relationship is further illustrated in Figure 4, which shows the total catch of target species and other species and the amount of target species shipped as the fishing period increases. This example assumes a daily catch rate of 250 kg.

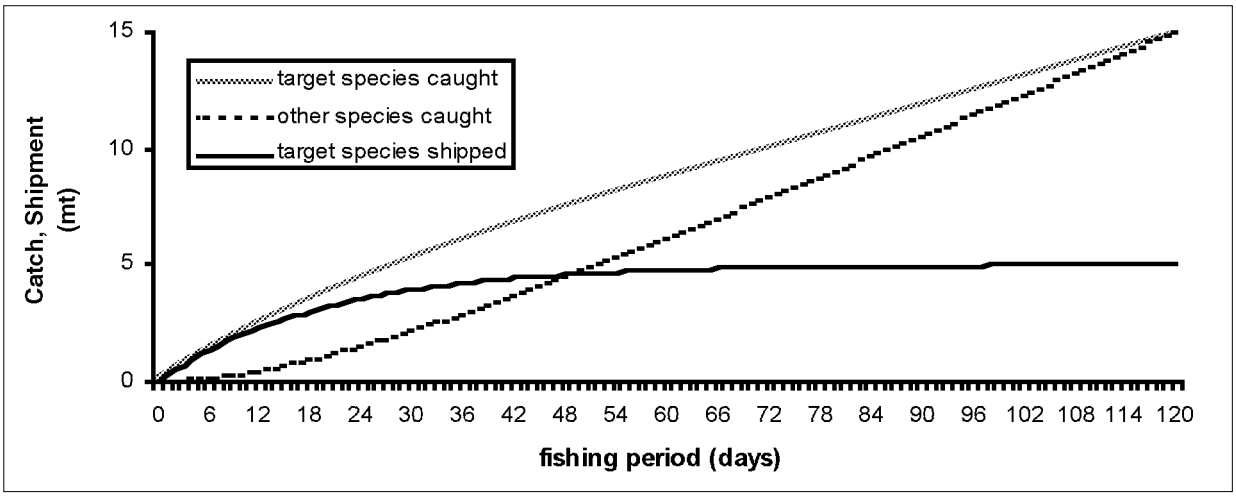
[23] "Safe yield" is just a crude device used here to describe what might widely be considered to be a reasonable and precautionary target for reef fish exploitation-it is not directly related to maximum sustainable yield, maximum economic yield, or any other theoretical target yields.

[24] In early 1995 Hatohobei State required the fishing company to start recording its catch and fishing effort in order to facilitate an assessment of the reef's potential production. Only about one month's worth of data were produced, probably not enough to make any conclusions about trends in catch rates, the productivity of the reef, or the effects of the operation. The data have not yet been examined in detail.

[25] Surveys in August 1999 and August 2000 revealed some *Plectropomus areolatus* and *Epinephelus fuscoguttatus* aggregating in the main channel (Guilbeaux, pers. comm., 2000), an area targeted by the 1994-1995 fishing operation, but there are no historical data with which to make comparisons.

[26] Although the two examined scenarios may represent the possible extremes in shipment rates, they do not represent the possible extremes in total catch. If the daily mortality rate or feed rate were 10 percent, for example, the total catch needed to deliver 1 kg of live fish would be between 6 and 12 kg.

Figure 4. Catch and shipment size, by fishing period



In the case of the recent Helen Reef operation, the fish were purchased by the Hong Kong-based importer upon loading in Palau, so any losses during shipping were borne by the buyer and not the exporter. But to the extent that these losses impact profitability of the industry as a whole-all the way to the consumer-the losses will be felt by the exporters and the fishermen in the form of lower prices

Shipping Mortality

While shipping by air has important advantages up to the point of shipping, it appears that the northern reef shipments by air suffered somewhat greater shipping mortality rates than the by-sea shipments from Helen Reef. Olikong reported that sometimes an entire air shipment of live fish was lost, especially during the early period of the operation. He estimated that, overall, the mortality rate during shipping was 60 to 75 percent. Patris reported shipping mortality for the Helen Reef operation to be 45 to 65 percent.

By-catch

By-catch has been cited as a problem in many live reef food fisheries. Richards (1993) reported that the catch in a live fishery in Papua New Guinea was comprised of only 10 percent target species. Donnelly *et al*. (2000) said that in Ontong Java and Marovo Lagoon, Solomon Islands, target species comprised 20 to 50 percent of the catch, and in Ontong Java, by-catch was excessive to the point that much could not be sold or consumed. These situations appear to contrast with the situation in Palau. First, at least for the by-sea operations, the problems associated with feed requirements would appear to outweigh any problems associated with by-catch (i.e., most or all of the by-catch would be needed to feed the target species). Second, it is doubtful that by-catch rates in Palau's fisheries have been as high as in the cases cited above.

It is noteworthy that the higher the observed by-catch rate, the less the likelihood that fishing was done on an aggregation of target species. In other words, to the extent that by-catch is a problem, fishing on aggregations can ameliorate it. As an extreme example, the catch from hand-lining on a mixed aggregation of *Epinephelus polyphekadion* and *Plectropomus areolatus* in Palau was 97 percent comprised, by number, of just those two species (n=3,046 fish; unpublished data from Palau Conservation Society).

In the northern reefs, fishermen sometimes have a difficult time selling their catches, due mostly to the expense of transportation to Koror. The by-catch from fishing for live fish, however, does not exacerbate that problem because fishing for live fish is mostly done instead of fishing for other purposes, rather than in addition to it. At Helen Reef, there was no alternative market for reef fish. However, the feed requirements for the live fish were so great that the by-catch alone did not meet the need-spearfishing and trolling had to be done to provide additional feed fish.[27]

It appears that by-catch has not been a large problem in Palau's live reef food fishery, but it is related to the problems related to feed requirements, discussed above.

Summary

Perhaps the most telling evidence regarding the productivity and sustainability of live reef food fish fishing in Palau is the similar statements offered by most of the principals involved in the fishery. Patris cited the depletion of fish on the reef-both target species and reef fish in general (fish caught for feed)-as the number one reason for stopping his operation. Olikong, whose operation had access to the substantial waters of Kayangel, Ngarchelong, and the eastern states of Babeldaob, said that there was not enough fish on the reef to support the industry (although he did not believe that fishing had any appreciable impact on stock size). Gibbons, whose operation had access to all the waters of Koror State, said that his operation needed access to additional fishing grounds in order to produce enough to make the business viable. The operation was not able to get permission to fish in any other states, so it quit. In short, all the principals interviewed believed that the productivity of the reef was a constraint to the viability of the industry.

Having said that, it appears that a more immediate constraint, at least for the by-sea operations, may have been the difficulty in mobilizing fishermen to fish hard enough to make shipments quickly enough to avoid the substantial penalties associated with long holding times. This is reflected in the comments by Liu and the small size of the single shipment his operation made, and by the apparently long holding times in the most recent Helen Reef operation.

4.2.3 Competition with Other Uses

In the main islands of Palau, fishing for live fish competes with fishing for subsistence and other commercial purposes, for both local and foreign markets-particularly Guam and Saipan. However, the participants in all these fisheries have been largely the same, so there has been no competition among fishermen, only the markets.

There are several non-extractive but direct uses of food fish resources in Palau-at least in the main islands. Dive tourism and sport fishing (i.e., catch-and-release fishing by tourists) both rely on healthy fish stocks, especially sport fishing. Dive tourism is centered in the waters of Koror and Peleliu, where fishing for live food fish has not occurred for 10 years. Palau does not have a well-developed reef-based sport fishing industry, but it has been government policy since the early 1990s to develop one, particularly in the northern reefs, where residents have few other opportunities

[27] In fact, Patris reported that some fish were thrown away, but that was probably only early in a given fishing period, before the daily feed requirements exceeded the daily by-catch.

besides extractive commercial fishing. The live food fishery clearly competes with that alternative value, even though it is as yet largely unrealized.

In the case of Helen Reef, there has been no alternative use of the resource, at least not any other extractive use-except by poachers and occasional visits from nearby islands, so direct competition has been virtually nil. In fact, the presence of the operation at the usually uninhabited reef may have served to deter foreign boats from poaching. On the other hand, the residents and leadership of Hatohobei State were clearly concerned about the impacts of the fishing operation on fish stocks, perhaps reflecting the value they place on future opportunities to fish (option value). The "conservation value" of Helen Reef and its resources, such as in terms of naturalness and biodiversity, have also been recognized, reflected in a number of international and local proposals to provide greater protection of the reef, including an ongoing initiative led by Hatohobei State. The live reef food fishery clearly competes with that value.

4.2.4 Distribution of Benefits

The business arrangements of the joint ventures that have dominated the fishery are not clear, making it difficult to assess the distribution of benefits and costs among the various participants. In order to provide a few rough indications, following are some notes on the perspectives of some of the players.

It is important to note that the fishery has undergone a clear evolution from purely foreign interest and participation to increasing ownership and participation by Palauans, and concurrently, increasing control by Palauan authorities.

Benefits to Local Fishermen

It appears that in most of Palau's live food fish operations, the fishermen were responsible only for delivery of just-caught live fish, not for storing or feeding them after capture. Ex-vessel prices for live fish have been about twice those for dead fish (most recently, $2 per pound, or $4.40/kg, in the northern reefs). The handling requirements for live fish appear to have been only marginally greater than for dead fish. There may have been slight additional costs associated with by-catch, but as noted above, the by-catch probably had as much value as it would have had in other fisheries (at least in the main islands). In the case of the most recent Helen Reef operation the local fishermen, as mentioned, were on salaries of $250 per month (and fishing at Helen Reef required being away from their homes for extended periods).

Interviews with the fishermen (except those at Helen Reef) and the principals involved in the operations almost invariably indicated general satisfaction on the part of the fishermen. On the other hand, in the case of the 1994-1995 northern reef operation, there were virtually no fishermen from Kayangel or Ngarchelong still participating by the end of 1995. The reasons are not clear. In the 1999 northern reef operation, which lasted only a couple of months, 12 of 15 "regular" commercial fishermen from the state of Ngarchelong participated in the fishery (Hoshina 1999).

In some of the operations there has been pressure from the buyers to fish intensively and consistently-possibly more hours and more often than most fishermen would like (as was Liu's experience on the Northern reefs). The by-air operation in the northern reefs, in contrast, did not have to fill carrier ships quickly, so it afforded the fishermen the flexibility to sell only a few pounds at a time.

But even in that case, the buyer expressed some frustration at not being able to obtain enough fish at certain times.

It appears that in general, the fishermen appreciated having the opportunity to fish for and sell to live reef food fish operations. But judging from their intermittent participation, they probably did not become highly dependent on those operations.

There is also the issue of competition between local and foreign fishermen. At Helen Reef, Patris estimated that the Chinese fishermen delivered at the end of a day three times as much live fish as the local fishermen and twice as much as the Filipino fishermen. At least in that case, there were clear business advantages to using foreign fishermen over local fishermen, but local interests ensured local participation. Patris described the role of the local fishermen not only in terms of employment opportunities, but also to maintain control of the foreign fishermen, and in particular, to ensure that they did not use cyanide. In the northern reefs, where the fishermen are known to be highly skilled at bottom fishing, the situation was probably closer to that described by Donnelly *et al.* (2000) for the Asia-Pacific region as a whole. They described a general trend of local fishermen being increasingly lured into the fishery by the high prices and the exporters increasingly finding it cheaper to employ local fishermen than to bring in their own.

Benefits to Local Communities

In some cases (e.g., the most recent Kayangel operation), the local state government was essentially a partner in the business. In other cases it was much less engaged, and in at least one case it was opposed to the operation. In fact, the small size of Palau's states and the lack of a clear line between the public and private sectors in the country make the distinction between the "community" (e.g., state) and the fishermen not entirely relevant. In the case of the Helen Reef operation, however, the state was clearly acting as a watchdog over the fishery. For example, it assessed fees on the business and it stipulated that future permission to fish would be contingent on an analysis of the productivity of the resource, based on catch reports that it required from the business. In the end, the closure of the operation appears to have been due, at least in part, to pressure from the state leadership to stop it, based on its concerns about the detrimental impacts of the fishery on Helen Reef's fish stocks.

As one very rough indication of what a live food fish operation might be "worth" to a local community, Hatohobei State charged the business at Helen Reef a fee of $1,500 for one year, plus $500 per shipment (of which at least three were done each year). It is not known what fees were assessed by other states in which live food fishing was done.

Benefits to Local Businesses

The opacity of the financial relationships between the local and foreign partners, along with the lack of access to financial records, make it very difficult to determine whether the local partners were satisfied with their returns.

Benefits to the Nation

In addition to the benefits generated through Palauan interest in and participation in the industry, the national government has had the opportunity to transfer economic rent from the fishing busi-

nesses and associated economic activity to the national treasury. As described above for the ornamentals fishery, there are several tax mechanisms available to do so.

As a rough exercise, at 25 mt exported per year and an export value of $10 per km, the annual export value of the live fish would be $250,000. Assuming that 20 percent was shipped by air, freight would generate another $50,000 in taxable spending. Assuming that wages paid in the industry were $75,000 per year, the gross revenue tax, at 4 percent of gross revenues less wages paid, would bring in about $10,000. The income tax, at roughly 8 percent of wages, would bring in about $6,000, and the import tax and other minor taxes might bring in a few thousand more, for a total of about $20,000 to the national treasury.[28] Thus, government revenues from live reef food fish represent only about one-tenth of 1 percent of total government revenues from domestic sources. To further put it in perspective, Palau's sashimi tuna export industry generates about $1 million each year in government revenue (PCS 1999).

Benefits Outside Palau

It is apparent that to the extent the fishery has generated benefits, substantial portions have gone to foreign interests. Palauan interest in the industry has been limited to the first two levels-fishing and exporting-and even in those two levels, it has usually shared interest with foreign fishermen and business partners. Lau and Parry-Jones (1999) estimated that importers in Hong Kong have "profit gains" of 5 to 8 percent (the meaning is not clear) and that wholesalers have profit gains of 20 to 30 percent through their sales, most of which are to restaurants. The final step is purchase by consumers, who enjoy some unknown level of consumer surplus (i.e., the gross benefit to consumers less their purchase costs).

In describing the termination of the Helen Reef operation, Patris said that his Hong Kong partners wanted to continue, but they were concerned about excessive local expenses that they were covering. They also regularly pressured Patris to replace the local fishermen with Chinese and Filipino fishermen, presumably because they believed them to be more efficient fishermen.

4.2.5 Summary

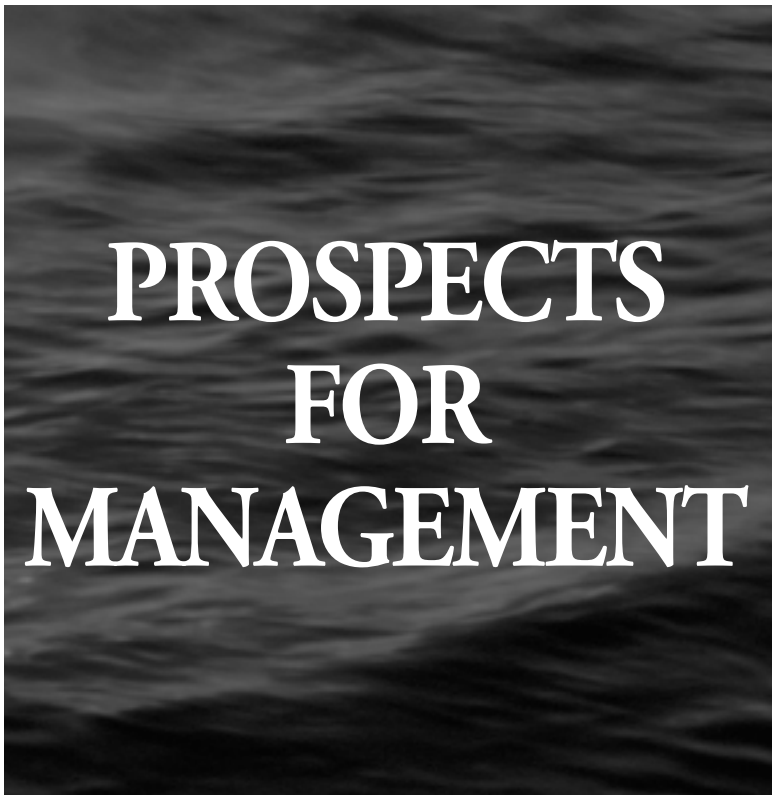
The rapid growth of the regional live reef food fish trade in the last 30 years suggests that it has been a profitable industry, at least to some of its participants. But the fact that fishing operations have continually moved from one fishing ground to another suggests that the industry lacks some of the attributes associated with long term viability. Bentley (1999) described the fishery in most regions as reaching a peak within three or four years, then declining. This pattern is not necessarily a negative characteristic of a fishery, and it is often done by design (e.g., pulse fishing trochus every two or three years). In the case of the live reef fish trade and Palau's experience in particular, however, it is indicative of problems regarding either the productivity of the resource or the distribution of benefits.

In Palau's case, it appears that a lack of adequately productive fish stocks has been the most important constraint to viability. Several other reasons appear to have contributed to the termination of sev-

[28] No research was done to determine the amounts actually paid through these taxes.

eral operations, including inadequate interest and fishing effort by local fishermen and resentment by local communities at seeing species important as food used as feed. But a lack of adequate fishing grounds or fish stocks was a reason cited for the termination of virtually every operation.

Just what impacts live food fishing has had on fisheries resources and their productivity is not clear, but there is strong evidence that live fishing operations have caused lasting impacts to grouper spawning aggregations. They may have also caused lasting impacts to populations of Napoleon wrasse, especially at Helen Reef, where a large number of fish was removed in a short time. It appears doubtful that the benefits of the live food fishery within Palau have exceeded the costs, especially after accounting for the external costs borne by the public. Either the costs of detrimental impacts to the resource were directly felt by the businesses through decreased production (and so they stopped), or the costs were felt by the public which then effectively transferred them to the businesses through public pressure to terminate operations.


PROSPECTS
FOR
MANAGEMENT

5. PROSPECTS FOR MANAGEMENT

As with any activity that exploits common resources, a key strategy for ensuring viability is to put in place mechanisms that internalize what would otherwise be external costs to the exploiter. For example, a fishing business might detrimentally impact the total value of the coral reef system, such as through losses to values associated with biodiversity or tourism. Unless the business is forced to avoid making those impacts (such as through gear restrictions, which from the business perspective constitute costs) or required to compensate the public for those impacts, the business will in effect be subsidized by the public. The subsidy will also encourage the continuation of a business that might, from the national or global perspective, be cost-ineffective, only helping to ensure a stream of negative returns in the future.

Effective management requires knowledge of the benefits and costs associated with an activity so that an appropriate portion of the costs borne by the public can be transferred to the industry. Such knowledge need not be rigorously accurate or quantitative, however. Anecdotal information, combined with common sense and a precautionary approach, can be adequate. The viability assessments in Section 4 were meant to do just that-to give a sense of whether the live reef fish industries have been, or have the potential to be, cost-effective for Palau as a whole.

One general strategy for minimizing externalities (e.g., transferring public costs to a private enterprise) is to strengthen and make more narrow (i.e., privatize) the property rights over the resource, such as through strengthening community control relative to national control. The importance of village-based marine tenure has been discussed in the context of live fisheries by Johannes and Lam (1999) and Kile *et al.* (2000), among others. In the case of Palau, the relatively high level of community control over fishing grounds has clearly been an important determinant of which live reef fish operations have been able to operate where, and for how long.

While strong local control over fishing grounds seems essential for management of any reef fishery, there are also important roles for the national government. They include supporting and harmonizing local-level management systems, providing fail-safe mechanisms (e.g., country-wide quotas or species restrictions), and in cases where an activity is deemed detrimental to the country under any circumstances, effectively pre-empting local authority through strict restrictions (e.g., a prohibition on the export of live reef fish).

5.1 OVERVIEW

Ornamentals

Between applicable state (at least Koror) and national laws, particularly the aquarium collecting regulations, Palau's fishery for ornamentals is probably as intensively managed as in any other Pacific Island country. Given the existing rules, the high level of compliance, the moderate size of the fishery, and the apparent lack of immediate threats to the resource, management can be judged as working reasonably well and not in need of major or urgent modification.

Although certain restrictions on trade-particularly on hard corals and live rock-may have impacted a past operation to the point that it went out of business, the apparent viability of the current operation suggests that there is room to work within the current legal framework. A number of relatively minor management issues are discussed in the following sections, with recommendations.

Food Fish

Unlike the fishery for live ornamentals, the live food fish trade has had readily apparent impacts on the resource, including depletion of target stocks and dramatic and possibly irreversible impacts on spawning aggregations.

At least a couple of the operations appear to have been stopped because of public pressure, expressed primarily through state leadership. This is positive in that it demonstrates that Palau's property regime-that is, strong state-level control of inshore resources-has been an effective mechanism for transferring what would otherwise be external costs to the industry. On the other hand, such transfer (through community reaction) has come only after a considerable amount of fishing and in some cases, substantial impacts to the resource. For that reason, it is recommended that the national government play a stronger role in managing the fishery, as it does in the fishery for ornamentals.

It appears that the best national policy would be to preclude further development of the industry, and the best way to effect that policy would be through strict restrictions on the export of reef resources. A summary of reasons follows:

- Given current prices, technologies, and airline routes, the prospects for even short-term profitability appear marginal, at best.
- Although the lack of profitability is not in itself a good reason for government intervention, the fact that new operations keep starting up, with attendant impacts to the resource, is.
- Add to the marginal profitability the external costs of resource degradation-or the risk of such degradation, and the possibility of the fishery bringing net benefits to Palau appears remote.
- Although the costs and risks associated with resource degradation could be minimized through government intervention (and transferred to the industry through restrictions and fees) the costs of doing so would be great.[29]
- The scale of export required for profitability appears to be great relative to what Palau's resources can sustainably produce, especially given that the "available" production is also constrained by competing extractive uses, particularly domestic consumption.
- Compared to the net value of the resource in the live food trade, alternative values appear to be great, including the values associated with domestic consumption, diving and fishing by tourists, and biodiversity, as well as option value (the value of retaining future opportunities to use the resource).

In the case that the fishery is left open, a number of management strategies are discussed below. There is also a local market for live reef food fish, with room for growth. Some of these strategies may be applicable to a fishery that targets the local market, even if exports are prohibited.

[29] For example, Johannes and Lam (1999) reported that the protection of spawning aggregations in Solomon Islands could reduce fishing efficiency to the point of non-profitability. Another example is that the public costs of creating and enforcing the management system necessary to implement a pulse-fishing regime would be substantial and possibly outweigh the benefits of doing it.

5.2 CONTROLS ON CATCH AND EFFORT

Ornamentals

The national government's limit of 20 collecting permits is ten times the current number of valid permits. The planned expansion of Belau Aquaculture would bring the number of permits up to 6 or 8, which would probably constitute slightly more than the greatest amount of collecting effort in Palau to date. Although even at higher levels of effort it is not clear that there would be any substantial impacts to the resource, a cap of less than 20 permits could be justified solely in terms of public perception of the fishery-that is, the bigger it gets, the more opposition there is likely to be, for whatever reasons. Whatever the available number of permits, they could be distributed among different areas of Palau to avoid excessive impacts in any given area.

The government should realize that the more permits it issues, the more effort it will need to devote to monitoring the fishery and enforcing the rules. For example, the greater the collecting effort, the greater the concern that should be paid to catch-per-unit effort for particular species and to the spatial and temporal dynamics of effort.

If effort and catch increase considerably, there may be reason to put in place quotas on export. Quotas on finfish have been implemented in the Maldives (100,00 fish; Edwards and Shepherd 1992) and have been recommended for Tonga (100,000 fish and 100 mt live rock per exporter; Matoto *et al.* 1996). The utility of putting a single quota on all fish species, however, is questionable since the impact of collecting will vary greatly among species. Further, given Palau's existing control on collecting effort through the limited entry system, there is little reason to also put quotas on large groupings of species. Quotas might be appropriate for particular species, however (discussed in Section 5.4).

It is recommended that if and when the number of collectors reaches 8 or 10, the government spread the collecting effort to states other than Koror through permit conditions, and/or that it consider reducing the cap from 20.

Food Fish

As with the ornamental fishery, the national government should play a strong role in the fishery, controlling exports and playing at least a role of coordinator with regard to access to the states' fishing grounds. This could be done through a permit system that provides for limits on participation in exporting, limits on fishing effort, quotas on catch or exports, and state permission for fishing. The permit system should be modeled on the system for ornamental collecting, and could be required of anybody exporting marine resources or information for commercial purposes. One important reason to make it broader than just live reef food fish is that the same operations that export live fish also tend to export chilled fish to the same markets, and the management issues for the two are essentially the same. Also, the same exporting companies will also supply-or be encouraged to supply-their buyers with other specialty marine products, such as ornamental species, shark fins, lobster, sea turtles, tridacnid clams, and trochus. The permit system could provide the means to restrict the export of these and other unforeseen products, whether or not other laws are in place to do so.

The Marine Protection Act provides for regulations to be promulgated by the Ministry of Resources and Development to further implement the act, but a permit system of this sort would probably exceed the authority of the act. It is unclear whether the Ministry would have the authority to do so under any other of its mandates. In any case, a new statute would provide the strongest and most effective mandate to do so. Such a statute could be introduced as part of, or as an alternative to, the bill to prohibit the export of reef fish.

As described in previous sections, Palau has had two very different types of live food fish fisheries-one type based on frequent small shipments by air and the other based on occasional large shipments by sea. Although the first type has disadvantages associated with high freight costs and high mortality during transport, it appears to be much more cost-effective up to the point of transport than the by-sea type. A fishery based on exports by air can best be managed through controls on the number of businesses, fishermen, fishing effort, and/or fish caught, with effort allowed to be spread widely through time and space to ensure consistency of supply (an attribute also important for the domestic market).

As illustrated in Section 4, a fishery based on shipments by sea would probably be better managed as a pulse fishery.[30] Details on how often and for how long fishing would take place are not discussed here, but the general strategy would be to provide regulatory and marketing mechanisms such that fishing is done intensively for brief and occasional time periods. A combination of seasons and individual or fishery-wide quotas (on catch and/or export) would probably be the best control. Some of the advantages of pulse fishing in the case of the fishing for live food fish follow:

- The pulse-fishing pattern might fit well with the desires of many local fishermen (as it does in the case of trochus collecting).
- Because participation by fishermen and fishing effort would be concentrated in a short time period, it would encourage relatively high daily catch rates, which, because of reduced mortality and feed requirements, would allow for greater fishing efficiency and fewer impacts on the resource for a given level of export.
- The short holding period would improve product quality and price.
- It would facilitate cost-effective transportation, minimizing the time and cost spent by carrier ships waiting in Palau's waters, possibly bringing higher prices.
- The pulse pattern of export might improve the local industry's ability to market its product among competing buyers.
- It would allow for relatively cost-effective enforcement of fishing and export restrictions, such as limits on catch, effort, or export, and restrictions on particular species, as most patrolling and other enforcement activities would be limited to brief periods.[31]

One cost of this approach is that it would require a substantial and consistent commitment by the government to do the analyses necessary to set effort (e.g., time) limits and/or quotas and to enforce those and other provisions. Johannes *et al.* (1999:93) emphasized that controls such as quotas are "much too complicated for most multi-species artisanal fisheries." Palau's most relevant experience

[30] A five-year alternating ban was discussed as an option for the Solomon Islands live reef food fishery by Kile *et al*. (2000). This option has some of the same attributes as the "pulse-fishing" strategy discussed here, but it was discussed by Kile *et al.* only in the context of ensuring sustainable use of the resources-that is, of allowing time for the resource to rejuvenate.

[31] As an example, if there was an annual live export quota of 50 mt, it could probably be taken in a one-month season. Enforcement of such controls as closed areas, restricted methods, and protected species could be limited to that one-month period, leaving only the need for routine monitoring of exports the rest of the year.

with such an approach has been in managing the trochus fishery, in which it actively and fairly successfully enforces season and size limits.

If managed as a pulse fishery, it might be unnecessary or counterproductive to maintain the existing four-month closure on fishing for groupers. This depends on how tightly fishing is controlled and whether or not it is advantageous to target spawning aggregations (to be discussed further in Section 5.5).

It should be noted that while quotas may be complicated to implement, they have the considerable advantage of directly controlling that which is most important to control-the number of fish removed from the water. Less direct controls, such as seasons, and particularly area closures, are coupled so loosely with the number of fish taken that it is difficult to gauge their impact. The result is that only relatively minor impacts on the number of fish taken may result from relatively costly restrictions to fishermen. If Palau's policy is to develop and maintain an export-based reef fishery, fishing efficiency is extremely important. It is restated here that it appears that the best policy is to keep the live reef food export fishery closed. If that policy is rejected, the second best would be to implement management strategies that control the catch as directly as possible and encourage efficiency in the fishing and handling stages, as discussed here.

If the export fishery is left open, it is recommended that the national government put in place a permit system like that for the ornamental fishery, including a cap on entry, effort, and/or catch. It is also recommended that the government further consider the costs and benefits of establishing a framework (e.g., fishery-wide and individual catch and/or export quotas combined with seasons) that would encourage or require pulse-fishing, particularly for operations that ship by sea.

5.3 RESTRICTIONS ON METHODS

Ornamentals

Belau Aquaculture said that the national restrictions on collecting methods did not detrimentally impact its operations. However, it argued that the exemption to allow the use of compressed air should be extended as a matter of course to ornamental collecting activities in general instead of granted on a by-permit basis. This could be accomplished through a change to the collecting regulations, but it seems to be a minor point, as the Minister of Resources and Development would be setting the policy in either case.

Food Fish

Current national restrictions on gears and methods are adequate and appropriate. Compliance does not appear to be a problem, but there is reason to be concerned about remote fishing areas such as Helen Reef and Velasco Reef, where poisons and explosives could be used with little risk of detection.

5.4 PROTECTION OF SPECIES

Ornamentals

Palau already has in place strict and effective prohibitions on the export of hard corals, sponges, and live rock and sand.

There may be some cause for concern about physical damage to the benthos during collecting. This could be investigated through occasional in-water observation by the government.

As collecting effort increases, impacts to particular species become of greater concern. Quotas on particular species could be implemented through the rule-making mechanism associated with the *Regulated Marine Species Register*. Such quotas have been implemented in the Maldives, where they were based on estimates of standing stock and surplus production for each species. The research done here was not intensive enough to reveal any species of particular concern, but again, as effort increases, the government should devote more effort to monitoring impacts to particular species.

Belau Aquaculture expressed concern that it was not permitted to export wild sponges and did not believe that a ban on their export was justified. One way to approach this would be through the definition of "cultured." Sponges, hard corals, and tridacnid clams may be exported if certified cultured, but the strict definition of cultured probably precludes any lagoon-based farming.[32] The definition could be relaxed such that the farming is limited to small areas of the lagoon, effectively forcing if not strict culture, then reliance on natural production from very small areas.

There has been widespread concern about the apparent waste associated with the capture of ornamental species not well suited to captive life, and recommendations have been made to restrict the trade of such species (e.g., Wood 1992; Edwards and Shepherd 1992). Restricting the trade of particular species solely because of what happens after consumption (that is, the government deciding what it is consumers want) is not good policy. Any such restrictions would likely be counterproductive. A market-based mechanism of providing such incentives to producers may soon become available through an independent certification program, discussed in Section 5.7.

It is recommended that as collecting effort increases, the government conduct more intensive evaluation of impacts on particular species and implement quotas or restrictions on particular species as appropriate.

Food Fish

The export prohibition on the wrasse, *Cheilinus undulatus*, is appropriate. No information was found that suggests that any grouper species warrants greater protection than any other. If needed, prohibitions or quotas on particular species could be administered as modeled in the aquarium collecting regulations. In addition, the permit system (recommended above) should be used to limit exports to particular "allowed" species, to help prevent the export of both regulated species such as sea turtles and giant clams and species not otherwise protected, including sharks.

[32] No one has ever taken advantage of the other exception to the export ban-organisms taken incidental to permitted dredging operations.

It is recommended that the export of all reef shark species be prohibited. This is related to the live food fish trade only insofar as traders of live reef fish tend to also trade in shark fins.

5.5 MANAGEMENT OF SPAWNING AGGREGATIONS

Food Fish

The catch efficiency afforded by spawning aggregations makes them appealing targets for live fishing operations. They also make aggregating species especially susceptible to overfishing, as described by Johannes *et al.* (1999). Aside from impacts to target populations, there is reason to be concerned about impacts to the aggregations themselves. That is, aggregations have qualities (even merely aesthetics) that make them valuable in and of themselves, beyond their importance in maintaining a given population. Clearly, management should aim to preserve aggregations.

However, this does not mean that aggregations should necessarily be completely protected from fishing. It is possible that the efficiency afforded by targeting aggregations could outweigh the risk of harming them. It is also important to note that it is not entirely certain that the protection of an aggregation from fishing is even a precautionary strategy with regard to maintaining that aggregation. In two aggregations studied in Palau by Johannes *et al.* (1999), fishing was found to have had negative impacts on the aggregations, not just in terms of numbers, but in terms of the aggregations' sex and age structures, as well.

At Ngerumekaol, in a relatively heavily fished area of Palau, remarkably low numbers of females (younger fish) relative to males (older fish) were found in an aggregation of *Plectropomus areolatus*. At Ebiil, in a somewhat less intensively fished area, a similar but somewhat less dramatically skewed sex ratio was found. Johannes *et al.* (1999) suggested that the ratios might be skewed enough to hinder spawning and reproductive success. It is known that older, bigger fishes (males) of this species tend to dwell deeper than the younger females when not aggregating, presumably making them less susceptible to capture than females when not aggregating.

The skewed sex and age structures of the two aggregations, therefore, may be more indicative of fishing pressure outside the aggregations than inside. It is doubtful that sex-selective fishing outside the aggregations could alone explain the odd sex and age structures observed (see Johannes *et al.* 1999 for discussion). Still, it is possible that closing the aggregation to fishing while leaving the fish susceptible to fishing outside the aggregations-that is, enhancing the ratio of outside-aggregation fishing pressure on the population to inside-aggregation fishing pressure-could actually exacerbate the aberrant sex and age structures and further hinder spawning and reproductive success. This point is not made to discount the potential effectiveness of protecting spawning aggregations from fishing. It is intended first, to point out that even that seemingly precautionary approach carries some risk, and second, to emphasize that the most important objective is to control fishing pressure on the population as a whole and it may be difficult to effectively do so solely through protection of spawning aggregations.

There were two scenarios presented above in which a live food fish industry might be viable. The first was low-level, spatially broad fishing, with frequent exports made by air. The second was intensive pulse fishing, with only occasional shipments made by sea or air. In the first case, fishing would

be spread widely through space and time. For that reason, it would be difficult to control the level of fishing on aggregations, and it would be best to protect them to the extent possible through seasonal and spatial restrictions. In the second case, there could be important advantages in targeting aggregations, some of which follow directly from the advantages of pulse fishing described above. Specifically, it would allow for:

- greater catch efficiency, making greater net benefits available overall;[33]
- less by-catch, reducing the costs associated with by-catch;
- more cost-effective enforcement, as patrolling could be limited to brief periods at discrete places and times;[34]
- cost-effective implementation of catch quotas; and
- cost-effective implementation of other restrictions, such as restrictions on size or sex (e.g., in order to manipulate the aggregations' sex and size structures).

These advantages must be weighed against the disadvantages, which include:

- possibility of a minor penalty to pay in terms of reproductive output by harvesting fish before rather than after they spawn;
- risk that fishing will disrupt spawning behavior and hinder spawning success;
- possible stress and death to captured females when they are ready to spawn, resulting in greater post-harvest mortality (as reported in Johannes and Lam (1999); and
- cost of a substantial and consistent commitment by the government to do the analyses necessary to set effort limits or quotas and to enforce those provisions. Johannes et al. (1999) argued that like quotas, this approach would be much too complicated, and further, that access to aggregations through permits would be too open to abuse.

Johannes *et al.* (1999) found that grouper spawning aggregations formed at all three study sites after the current closed season for groupers, which extends through July, and it was recommended that the closed season be extended through August. To the extent that the aggregations should be protected from fishing (see above), this would be sound policy, and consideration might even be given to a closure through September if new data support it.

5.6 AREA RESTRICTIONS

Ornamentals

Just as protected areas are widely recommended as a conservation strategy for managing any fishery, they are often recommended specifically for ornamental fisheries. Edwards and Shepherd (1992) recommended that collecting in the Maldives be confined to designated areas that collectively made up 10 to 20 percent of the reef area customarily used by collectors. Tissot (1999) described a new Hawaii State law that closed 30 percent of the west coast of the island of Hawaii to aquarium fish collecting.

[33] The catch rate of *Epinephelus polyphekadion* while aggregating reached greater than 10 kg per fisherman-hour on some days (unpublished data from Palau Conservation Society), compared to a typical rate of about 1 kg of target species per fisherman-hour in the live fishery at Helen Reef. As described in Section 5, greater catch rates pay off in terms of not only fishing costs, but also the costs associated with feeding and holding mortality.

[34] The more limited in time and space that fishing becomes, the more cost-effective enforcement becomes. At some point it would even pay to have essentially 100 percent enforcement coverage, such as through the continual presence of observers or enforcement officers on mother or transport vessels.

Area restrictions can serve not only to protect the resource, but also to separate user groups and avoid conflict. Palau and Koror already protect many popular tourist areas from fishing of any sort. Further area restrictions for either purpose do not seem necessary at this point, but areas that might need protection can be identified through the Rock Islands management process now getting underway.

Food Fish

Existing national and state restrictions keep all fishing out of many of the most popular tourist areas. Four important grouper aggregations and several smaller ones are at least nominally protected through state and traditional law, but enforcement is difficult and compliance probably not very good. Fishing for live fish should be further restricted by area, either to avoid other known aggregations, or to allow and encourage fishing on aggregations under controlled conditions, as discussed above.

5.7 EFFICIENCY

Ornamentals

Much of the waste associated with post-harvest mortality constitutes a cost that is borne directly by the producer, so it is in the producer's interest to minimize such mortality. However, to the extent that collecting causes impacts to common resources (the reef), some of the costs associated with collecting (and thus mortality) are borne by the public. Unless provided with incentives through law or the market, the producer has no interest in minimizing those costs.

There is a major initiative underway, headed by the Marine Aquarium Council, to create a certification program for ornamental marine products (see Baquero 1999). The program would provide the means for consumers to more effectively express their desires for certain product attributes, such as fish that are captured using non-destructive methods and handled under control standards designed to minimize mortality. This system is about to enter a testing phase, and it is too early to determine what the costs and benefits of certification will be (e.g., what premium consumers will place on certified product).

The Pacific Islands have a reputation for supplying ornamental products that are caught without the use of destructive methods (Baquero 1999). Belau Aquaculture believes that it receives a small premium for its "hand-caught" product. If this advantage were expressed through certification, the reputation would be enhanced and the premium might increase. However, to the extent that product from other countries, particularly from the Philippines and Indonesia, becomes certified, the premium currently placed on Palauan products is likely to be eroded. Given the magnitude of destructive fishing and other problems in Asia, this is certainly not an immediate concern, but it is in the local industry's interest in any case to explore any opportunities to enhance the reputation of its product.

The certification program is a purely market-driven and industry-run initiative, without any need for local government intervention. No management recommendations are therefore made here except to say that the national government should consider ways that it could facilitate the certification process for Palauan businesses, such as through export inspections and its own endorsements.

There is one government restriction in particular that hinders efficiency-the Palauan-only collector rule. It is addressed in Section 5.8.

Food Fish

Strategies for encouraging efficiency in the live reef food fishery were addressed in the previous sections.

As in the fishery for ornamentals, there are initiatives underway to improve the flow of product information to consumers of live fish through labeling or certification mechanisms. It is not even clear in the case of live fish how much premium consumers are willing to pay for product attributes that minimize waste and detrimental impacts to the resource.

5.8 INTEREST AND PARTICIPATION OF PALAUANS

Foreign investment law provides that reef fish fishing businesses must be wholly Palauan-owned. Foreign fishing law provides that foreign vessels may not fish for reef fish. These rules do not prohibit foreign interest in the storage and export parts of the industry.

That financial interest in reef fishing enterprises is limited to Palauan citizens is part of a national policy much broader than the context of fishery management, and it will not be further addressed here.

Ornamentals

The provision that restricts collecting to Palauans has a similar purpose to the restriction on foreign investment. Strict enforcement of the provision would certainly curtail collecting efficiency and profitability, at least for a number of years.[35] Principals in the industry contend that it would take at least ten years and considerable effort to see any Palauans trained to the point that they would be competitive with Filipinos.

It is recommended that the government seek and consider public input regarding the advantages and disadvantages of allowing foreign collectors, and to shape policy accordingly.

Food Fish

No further restrictions seem necessary, but the national government (if it implements a permit system) and the states could further restrict foreign interest or participation on a case by case basis as they see fit.

[35] Belau Aquaculture estimated that a Palauan collector with one year of experience would have a collecting efficiency about one third that of an experienced Filipino collector.

5.9 NATIONAL-STATE COORDINATION

The *Regulations on the Collection of Marine Resources for Aquaria* and Research provide an important (if not yet well tested) model for clarifying the respective roles of the national and state governments with regard to the management of marine resources. The regulations include moderately intrusive measures by the national government-deciding who may do business in the industry, allowing only Palauans to collect, and prohibiting the export of certain species. However, they also provide important recognition of state control over inshore resources, to the point that they make it a national offense to collect without the explicit permission of a given state. Given that the balance of power between the national and state governments will always be delicate and sometimes contentious, the system appears to be working reasonably well. The same model could be applied to other (or all) export fisheries, including live food fish, research, and bioprospecting, as suggested in Section 5.2.

The states will not always have clear or written policies about particular activities such as ornamental collecting. This is not a critical problem, but it is in the national interest to help the states rationalize and clarify their policies (for the sake of stability, if nothing else-see Section 5.14). For example, neither compressed air nor any small-mesh nets may be used to fish in the waters of Koror. Yet Koror has permitted a business that is clearly dependent on that gear. Perhaps most importantly, the national government can help the states assess the value of a given type of enterprise so that the states can levy appropriate fees on their permittees, as discussed in the next section.

It is recommended that the DMR work closely with the states to harmonize and rationalize to the extent possible their laws and policies with regard to export fisheries, including ornamentals and live food fish.

5.10 EXTRACTION AND DISTRIBUTION OF ECONOMIC RENT

The national aquarium collecting regulations are intended to control entry into the ornamentals fishery but not to extract rent from the industry (a national collecting permit costs $100 per year-enough only to cover some administrative costs of management).[36] The regulations implicitly leave that right to the states, as owners of the resource. The licensing system of Koror State provides for the collection of only $120 per year from a commercial net fishing operation and $300 from a hook-and-line vessel, with the permits allowing as many as 11 people to fish at once. For many extractive activities, live reef fisheries included, this modest fee would effectively undervalue the resource. Koror appears to have recognized that, as it recently charged Belau Aquaculture $500 per year, apparently through a contract. While the states will always have the option to treat businesses in this way-that is, outside any statutes they have specifically for fishing, codifying such a contractual framework would serve both to encourage "fair" assessments of compensation and to legitimize the practice in the eyes of the public and the national government.

It is recommended that the states put in place provisions for assessing reasonable fees on marine resource-dependent businesses, such as live reef fish operations. This could be through a permit requirement that is dependent on contractual agreements negotiated on a case by case basis. This same framework could be used for any relatively high value and/or extractive marine uses, includ-

[36] It is not clear why or under what authority the national government appears to be charging $300 instead of $100.

ing export food fisheries, research, and bioprospecting. A possible criterion for having the provision apply would be whether or not any product or information is exported from Palau.

The national government has the ability to extract rent from the live reef fisheries through several taxes (roughly estimated in Section 4.1.4 and 4.2.4 at $20,000 per year for each of the two fisheries). The principals of Belau Aquaculture argued that it should be made exempt from the tax because it is a wholly Palauan-owned business that brings in foreign exchange. The government has not had any policies that reflect that argument, although in the early 1990s it provided a temporary exemption for tuna and copra exporting businesses in order to encourage investment in those industries. Another tax issue not specific to the export fishing industries is the matter of "double-taxing." Because revenues from freight charges pass through Belau Aquaculture, the business would appear to be liable for gross revenue tax on those revenues, as is the freight carrier, which collects revenues for freight from Belau Aquaculture. Being matters of national policy relevant to the entire economy, these two issues will not be addressed further here. One or both may, in fact, be addressed by the national tax reform initiative currently underway.

If a fishery requires substantial inputs into management, including the costs of monitoring and analysis, administration, and especially enforcement, there should be mechanisms in place to ensure that a fair portion of those costs-probably all of them-are transferred from the government to the industry. Both of the live reef fisheries require substantial management inputs. The food fishery, especially, if left open, would require substantial government control, perhaps to the point of keeping observers or enforcement officers on board catcher or holding vessels. Fishing permit fees would be a simple mechanism for handling these costs. A special tax on exports of live fish, as is done for exports of tuna and billfish, would be another way. The management requirements for the ornamentals fishery are not prohibitive, but if collecting effort increases, greater investment in management would be justified, along with correspondingly greater tax or fee burdens on the industry.

5.11 CULTURED PRODUCTS

Ornamentals

The definition of "cultured" in the aquarium regulations (for the purpose of allowing exports of hard corals, tridacnid clams, and sponges) is very strict, and even the tridacnid clams grown at the PMDC may not meet the criteria for certification. The national government may want to reconsider and relax the definition of cultured so as to allow and encourage economically feasible mariculture that has minimal-if not zero-impact) on wild stocks.

Food Fish

In collaboration with the Japanese government, the DMR is conducting a project aimed at spawning and raising several species of grouper, all of which are important in the live food fish trade. The stated objectives of the project are to raise fingerlings that would be released on the reef to augment natural stocks. An implied and perhaps more important objective is to make a breakthrough in hatchery and raising methods, particularly for the plectropomids, which have resisted farming efforts in other countries. Although such a breakthrough would be a boon to Palau's reputation and might give it a head start in commercial culturing of groupers, the technology would be available to

all countries, and it would be unlikely to give Palau any distinct advantage in the live food trade. As with most cultured products, Palau has few advantages relative to potential sources in Asia.

5.12 MONITORING

The current reporting requirements cover just about every conceivable need for data from live fishing operations. The only limitations are the government's imperfect enforcement of the requirements and the lack of data compilation and analysis.

There are also requirements for detailed catch and effort data from businesses that export fish for commercial purposes, but they appear never to have been complied with and never to have been enforced by the DMR.

Ornamentals

The ornamentals industry has largely met the export reporting requirements during the last few years, allowing for easy tracking of major trends. The required catch and effort data, which have never been reported, could be very useful for detecting limits to the productivity of the resource, but they would require substantial effort by the government or others to analyze. For example, if ornamentals collecting efforts are observed to continuously move from area to area, with long intervals between collecting in a given location, this could indicate relatively low productivity and high impacts by the fishery.

It is recommended that as collecting effort increases, the DMR strengthen compliance with the reporting provisions of both the aquarium collecting and export regulations. A simple logbook for ornamental collecting businesses could be devised to ensure easy and meaningful data collection. The data could be analyzed every year or two, if necessary with the assistance of any number of organizations, including the PICRC and PCC.

Food Fish

If fishing for live reef fish for export is allowed, the national government should ensure thorough reporting by the operations, starting with exports and moving to catch and effort as capabilities allows. If managed under an effort limit or catch quota, catch and effort reporting would be essential not just for stock assessment purposes, but for enforcement, as well. Clearly, a live reef fish export fishery should only be allowed if the government is committed to periodically undertaking the considerable analysis necessary to set and evaluate limits on entry, effort, and/or catch.

5.13 ENFORCEMENT

Ornamentals

Enforcement of the export reporting requirements, along with the inspections of shipments routinely done by the DMR, allows for cost-effective enforcement of most applicable national laws.

It is recommended that national and/or state officers occasionally observe collectors in the water. This would not necessarily only serve to observe violations, but would help to better assess the likelihood of violations occurring and to identify the impacts of even legal methods, such as incidental breakage of corals while collecting fishes.

Food Fish

Enforcement of the laws that apply to live food fishing operations has been poor, in part because much of it would have to be done at sea. Many shipments appear to have been made, for example, without customs clearance through Koror. It is essential that the government provide accurate monitoring of exports, including inspections of all exports by sea and at least occasional inspections of exports by air. Again, a much greater enforcement commitment by the national government would be required to enable a viable fishery.

Under customs law, vessels entering and leaving Palauan territory must clear through Palau's only port of entry, Koror. The same requirement could be made specifically for live food fish carriers in fisheries law, giving the Ministry of Resources and Development the authority to enforce it, and facilitating enforcement of other laws.

5.14 STABILITY OF MANAGEMENT SYSTEM

An important issue in both live reef fisheries, but especially the ornamentals industry, has been the lack of stability in the management regime. Several major changes in the rules since 1991 have made the system appear unpredictable, making it risky for businesses to enter the fishery. It is important to the private sector that the basic components of the system be stable and predictable, and that they flex only in pre-established ways. The current national system for the ornamentals fishery-a system that has not changed since 1994-provides such a framework. It puts limits on effort through a limited entry system, with the actual limit adjustable from year to year. It also offers a flexible mechanism for putting limits or conditions on the take of particular species.

While the current administration appears to be implementing the system as designed, there is always the possibility that the legislature will start again from scratch. It is considering a bill, for example, that would prohibit the export of any reef fish, including ornamentals. The states, with their ultimate control over access to their reefs, are also capable of making the national system irrelevant. Although state-level control is essential, it is important that the national government (DMR) work closely with the states to harmonize and stabilize their policies to the extent possible, and as implied above, to keep the legislature well-informed on the status, value, and impacts of the fisheries.


FUTURE
ACTION

6. FUTURE ACTION

Following is a list of specific actions that could be considered by relevant agencies and organizations in order to improve management of Palau's live reef ornamental and food fish fisheries.

6.1 OUTREACH

1. Produce and disseminate educational materials, such as fact sheets and videos, on relevant topics about reef fish resources; PCS has already compiled much of the necessary information. Important topics to be covered include:

   - The actual and potential productivity of Palau's reefs, trends in harvest and other uses, the various and competing uses of reef fish, forecasted growth of those uses, and implications of exporting reef fish and other resources - the target message should be that keeping these resources in Palau is, with some exceptions, sound precautionary policy (Palau's recommended population policy (PNCPC 1997) provides a good example of how to frame the issues).
   - The results and implications of the grouper aggregation study (Johannes *et al*. 1999).

6.2 NATIONAL POLICY AND MANAGEMENT

1. Seek resolution of the debate over the bill that would prohibit the export of reef fish:

   - Using the awareness materials described above and other means, ensure that lawmakers and the public are adequately informed about the issues related to the export of reef fish resources.
   - Prepare and introduce a modification of the bill that would prohibit the export of reef fish (PCS has already prepared several versions).[37] Among other things, the revised bill should provide appropriate exemptions and controls for ornamental products, bioprospecting and research, and the export of reef products for non-commercial purposes (e.g., exempt processed product).

2. In the event that the national government adopts a policy of allowing live reef food fishing for export (or fails to adopt a policy that would preclude it), the management regime for the fishery-as administered by the Ministry of Natural Resources and Development and its agencies-should be strengthened, including:[38]

   - Draft and adopt regulations that would establish a permit system and related provisions for any reef fishing for export for commercial or research purposes. The system should be modeled on, and perhaps incorporated into, the existing system for the ornamentals fishery. It should provide, among other items, permit requirements for export, prohibitions on the export of all but specific target species, quantitative limits on catch, effort, and/or exports (e.g., through fishery-wide and/or permit-specific quotas), and requirements for permission from the states to fish. It should also include mechanisms to ensure that the full costs of

[37] See Johannes *et al*. (1999) and PNCPC (1997) for further justifications of an export prohibition in Palau, and Birkeland (1996) for arguments in favor of such prohibitions for tropical islands in general.

[38] Even if the live food fishery for export is essentially closed by the government, the components described here could be useful for other reef fish export fisheries, and in any case, it is recommended that the provisions be applied to any and all reef fishing for export, with possible exemptions for non-commercial activity.

management are transferred to the industry, such as through permit fees or a special tax on exports of live fish. Promulgation of such regulations may require legislative action (i.e., they would probably go beyond the authority delegated by the Marine Protection Act). If so, the mechanism could be offered as an alternative solution to the strict prohibition proposed in the reef fish export bill being considered by the Fifth OEK.

3. Strengthen national government enforcement of laws applicable to the live reef fisheries, including:

   - Regular inspections of exports and enforcement of reporting requirements for both exports and catch and effort (Ministries of Natural Resources and Development and Administration).
   - Occasional on-water and in-water enforcement of area, method, and season restrictions, possibly through vessel observers if warranted (Ministry of Natural Resources and Development).
   - Improving compliance by food fishing operations through better enforcement of customs laws that require vessel clearance through Koror (Ministry of Administration)
   - Prevention of poaching by foreign live food fish vessels through adequate patrols, particularly in the Southwest Islands and the far northern reefs (Ministry of Justice).
   - Better coordination among the Ministries of Natural Resources and Development, Administration, and Justice.
   - (Division of Customs), and Justice (Division of Marine Law Enforcement).

4. Further consider the pros and cons of extending the grouper fishing closure through the month of August (or even September), particularly as it depends on whether exports of live food fish are prohibited, how tightly the export fishery is controlled (e.g., towards pulse fishing), and whether or not spawning aggregations should be targeted (see Johannes *et al.* 1999, for arguments in favor of an extension of the closure).

5. If and as collecting effort for ornamentals increases, it should be forced to spread out geographically through appropriate conditions on the national collecting permits.

6. If evidence is found that suggests detrimental impacts to particular ornamental species (see Section 6.5), reduce the impacts through species-specific quotas on catch and/or export, using the rule-making mechanisms of collecting regulations.

7. Improve national-state co-management of inshore marine and fisheries resources, such as through national laws that would clarify jurisdiction authority and that would create a cooperatively managed system of protected areas (see Graham, 2000).

8. Pursue policies that encourage development of the local market for live reef fish.[39]

9. Every few years, and with public input, re-evaluate the policy of allowing only Palauan ornamental collectors.

10. Consider relaxation of the definition of "cultured" as needed to facilitate development of low-impact culturing of hard corals, soft corals, tridacnid clams, and sponges.

[39] PCS had plans to evaluate the development of that market, but work so far has been limited to a description of trends in the inshore fishery (PCS, 2000).

11. Ensure that adequate mechanisms are in place to prevent the export of incidental species, including both illegal (e.g., sea turtles and tridacnid clams) and legal species (e.g., reef sharks).

6.3 STATE POLICY AND MANAGEMENT

1. Strengthen the fishing permit systems of the states, particularly Koror, Kayangel, Ngarchelong, and Peleliu. The systems should include permit requirements for any person or company that extracts and exports marine resources or marine information for commercial or research purposes. They should provide default, or base fees, plus provisions for the state to require, as it deems necessary or negotiates on a case by case basis, additional fees and additional terms of access, established through contractual agreement.

2. Provide support as needed to the states and to their partners, such as PCS and the BNRD, with local conservation area initiatives, including:

   - Ensure that technical, legal, and financial support is available to see effective management of Ebiil Conservation Area.
   - Facilitate discussion with Ngarchelong regarding the possibility of providing stricter protection for the aggregation site at Western Entrance, perhaps in the context of sport fishing development (see Johannes *et al.* 1999 for a detailed rationale).
   - Management of the Ngeremeduu Conservation Area, and specifically, managing fishing and the Toachel Mlengui aggregation site.

3. Ensure that both the ornamentals and live food fisheries are adequately addressed in the management plan development process for the Rock Islands, considering such options as:

   - Closed areas and/or open zones for collecting ornamentals in order to avoid conflict with tourism and other sectors and to protect any ecological critical areas, as they are identified;
   - mariculture zones for ornamentals and other products;
   - protection of aggregation sites from some or all fishing, including Mutiaur, Denges, Siaes, and Rebotel; and
   - using the initiative as an opportunity to improve Koror's and Peleliu's permitting systems for fishing, as described in item 1, above.

4. With the national government, seek rationalization and harmonization of state policies and laws affecting fisheries-for-export, including permit systems and method restrictions.

6.4 INDUSTRY

1. Support as needed the efforts of the Marine Aquarium Council to develop a certification program for ornamental products, such as facilitating Belau Aquaculture's participation in the testing phase of the program, due to start in the next few months.

2. As new live food fishing operations establish themselves in Palau, ensure that the local partners are adequately educated on the impacts of the trade and best practices for fishing, handling, and fishery management.

6.5 RESEARCH AND MONITORING

1. More rigorously assess the benefits and costs of export-based reef fish fishery, including live reef food fish in particular. The assessment should take advantage of general analyses done in the region, complimented with Palau-specific information as necessary. Key elements to take into account include the productivity and vulnerabilities of target resources, prices, and operating costs, competing uses of target resources, the needs and aspirations of local communities, and the capacity to cost-effectively manage the fishery.

2. Assess the costs and benefits of seeing full compliance with the catch and effort reporting requirements of the aquarium collecting and marine export regulations (which apply to both the live ornamental and food fish fisheries), and seek compliance as appropriate (enforcement of the requirements by DMR would only be worthwhile if there is the capability and commitment to consistently and thoroughly analyze the data and to apply the results-conditions that do not currently exist). For example:

   - Develop a simple logbook system for tracking fishing and collecting effort and catch by area.
   - Develop a simple analytical tool for detecting significant changes in catch and catch-per-unit-effort for particular ornamental species, using both sales data already collected and catch-effort data, if collected.

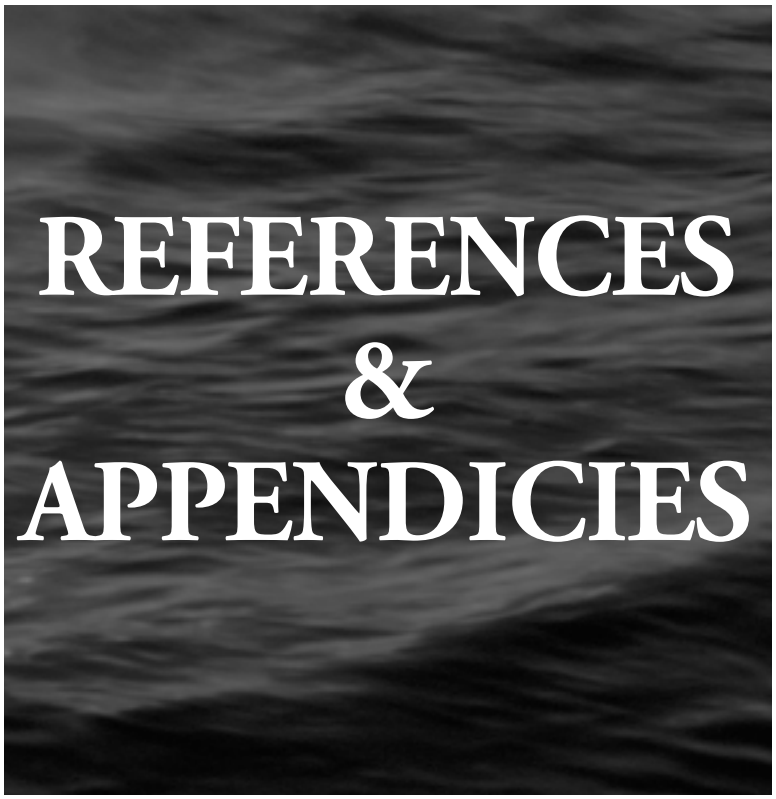
3. To the extent that the national government supports or tolerates the live food fish fishery:

   - DMR should undertake, with the necessary technical support, the analyses necessary to set limits on entry, effort, catch, seasons, or other necessary controls.
   - Further analyze the advantages and disadvantages of a management framework that would facilitate pulse fishing (versus steady fishing) and fishing on aggregations in order to improve efficiency and decrease detrimental impacts to the resource, as discussed in Section 5.

4. Conduct cost-effective monitoring of spawning aggregations (e.g., by DMR, PCS, the PICRC, Koror, and other states), including:

   - Develop standardized and site-specific monitoring protocols.
   - Develop analytical capacity and procedures, including development of automated analytical tools.[40]
   - Strengthen the scientific and management capacity of Koror State.
   - Provide occasional training courses in underwater fish monitoring methods.
   - Develop an effective cadre of underwater monitoring specialists across all agencies, organizations, and jurisdictions.

[40] The database and analytical tools used by Johannes *et al.* (1999) could be fairly readily adapted to long-term monitoring purposes.


REFERENCES
&
APPENDICIES

7. REFERENCES

Baquero, J. 1999. *Marine Ornamentals Trade: Quality and Sustainability for the Pacific Region.* South Pacific Forum Secretariat, Suva, and the Marine Aquarium Council, Honolulu.

Bentley, N. 1999. Fishing for solutions: can the live trade in wild groupers and wrasses from Southeast Asia be managed? *Live Reef Fish Information Bulletin* 6: 25-27. Secretariat of the Pacific Community, Noumea, New Caledonia.

Birkeland, C. 1996. Implications for resource management. Pp. 386-410 in C. Birkeland, ed. *Life and Death of Coral Reefs*. Chapman & Hall, New York.

Chan, P.S.W. 2000a. The industry perspective: wholesale and retail marketing aspects of the Hong Kong live reef food fish trade. *Live Reef Fish Information Bulletin* 7: 3-7. Secretariat of the Pacific Community, Noumea, New Caledonia.

Chan, P. 2000b. Current status of the live reef fish trade based in Hong Kong. *Live Reef Fish Information Bulletin* 7: 8-9. Secretariat of the Pacific Community, Noumea, New Caledonia.

Dalzell, P. 1996. Catch rates, selectivity and yields of reef fishing. Chapter 7 in N.V.C. Polunin and C.M. Roberts, eds. *Reef Fisheries*. Fish and Fisheries Series 20, Chapman & Hall.

DMR. (No date.) *Division of Marine Resources Annual Report 1992*. Bureau of Natural Resources and Development, Koror, Palau.

Donnelly, R.J., D.C. Davis, and M. Lam. 2000. *Socio-Economic and Biological Aspects of the Live Reef Food Fish Trade and its Development in Solomon Islands*. Discussion Paper No. 1. Report to the Australian Centre for International Agricultural Research, Canberra: 52 pp.

Edwards, A.J. and A.D. Shepherd (1992). Environmental implications of aquarium-fish collection in the Maldives, with proposals for regulation. *Environmental Conservation* 19(1): 61-72.

Eichhorst J. 1994. Memorandum from J. Eichhorst, Assistant Attorney General, to Chief, Marine Resources Division, Republic of Palau.

FFA/DMR. 1995. *Republic of Palau Marine Resources Profiles*. Research Coordination Unit, Forum Fisheries Agency, Honiara, Solomon Islands, and Palau Division of Marine Resources, Koror, Palau.

Guilbeaux, M. (Pers. comm.) 2000. Community Conservation Network, Honolulu.

Graham, T. 1995. Managing Palau's aquarium life fishery. In *South Pacific Commission and Forum Fisheries Agency Workshop on the Management of South Pacific Inshore Fisheries.* P. Dalzell and T.J.H. Adams, compilers. South Pacific Commission, Noumea, New Caledonia. Vol II: 75-85.

Graham, T. 2000. *An Assessment of the Role of The Nature Conservancy in Palau*. The Nature Conservancy, Asia Pacific Program, Koror, Palau.

Hoshina, H. 1999. *Report on the Survey of the Fishing Cooperative Association in Ngarchelong State in the Republic of Palau*. Ministry of Commerce and Trade, Koror, Palau.

Hoshina, H. (Pers. comm.) 2000. Cooperative Coordinator, Japan Overseas Cooperation Volunteers, Koror, Palau.

Johannes, R.E. and M. Lam (1999). The live reef food fish trade in the Solomon Islands. *Live Reef Fish Information Bulletin*, 5:8-15, Secretariat of the Pacific Community, Noumea, New Caledonia.

Johannes, R.E. and M. Riepen (1995). Environmental, Economic, and Social Implications of the Live Reef Fish Trade in Asia and the Western Pacific. The Nature Conservancy, Honolulu.

Johannes, R.E., L. Squire, T. Graham, Y. Sadovy, and H. Renguul. 1999. *Spawning Aggregations of Groupers (Serranidae) in Palau*. Marine Research Series Publication No. 1, The Nature Conservancy, Honolulu: 144 pp.

Kile, N., M. Lam, D.C. Davis, and R.J. Donnelly. 2000. *Managing the Live Reef Food Fish Trade in Solomon Islands: the Role of Village Decision-Making Systems in Ontong Java, Roviana and Marovo Lagoons*. Discussion Paper No. 2. Report to the Australian Centre for International Agricultural Research, Canberra: 28 pp.

Kitalong, A. and E. Oiterong. 1991. *Review of the Grouper Fishery in Palau*. Technical Report 91.4, Palau Division of Marine Resources, Koror, Palau.

Lau, P.P.F. and R. Parry-Jones. 1999. *The Hong Kong Trade in Live Reef Fish for Food*. TRAFFIC East Asia and World Wide Fund for Nature Hong Kong, Hong Kong.

Matoto, S., E. Ledua, G. Mou-Tham, M. Kulbicki, and P. Dalzell. 1996. *The Aquarium-Fish Fishery in Tongatapu, Tonga; Status and Recommendations for Management*. South Pacific Commission, Noumea, New Caledonia: 24 pp.

PCS. 2000. *Profiles of Palau's Inshore Fisheries*. Palau Conservation Society, Koror, Palau.

PCS. 1999. *Palau's Locally Based Foreign Tuna Fishery: Benefits and Costs to Palau*. PCS Report 99-02, Palau Conservation Society, Koror, Palau.

PNCPC. 1997. *Population and Development: Toward a Palau National Policy for Sustainable Human Development.* The Palau National Committee on Population and Children, Koror, Palau: 87 pp.

Pyle, R.L. 1993. Marine aquarium fish. Chapter 6 in A. Wright and L. Hill, eds. *Nearshore Marine Resources of the South Pacific; Information for Fisheries Development and Management*.

Richards, A. 1993. Live reef fish exports to South-East Asia from the South Pacific. *SPC Fisheries Newsletter* 67: 34-36. South Pacific Commission, Noumea, New Caledonia.

Rochers, K. and L. Matthews. 1992. *Marine and Terrestrial Resource User Survey*. The Nature Conservancy, Honolulu.

Tissot, B.N. 1999. Adaptive management of aquarium fish collecting in Hawaii. *Live Reef Fish Information Bulletin* 6:16-19. Secretariat of the Pacific Community, Noumea, New Caledonia.

Wood, E. 1992. *Trade in Tropical Marine Fish and Invertebrates for Aquaria: Proposed Guidelines and Labelling Scheme*. Marine Conservation Society, Herefordshire.

Appendix 1. Air Cargo Rates from Koror

Destination	Air Cargo Rate (US$/kg)					
	< 45 kg	> 45 kg	45-100 kg	100-300 kg	300-500 kg	> 500 kg
Los Angeles	8.53		6.52	6.03	4.92	4.09
Hong Kong	4.98	3.74				
Manila	2.75	2.07				
Taipei	6.59	4.94				

- All rates are for and as advertised by Continental Micronesia.
- Rates effective as of September 2000; the Hong Kong rates, at least, have not changed since at least 1995.
- Only the Manila route is direct; the others go through Guam.
- Belau Aquaculture currently pays $3.40/kg for shipping to Los Angeles.
- The Air Pacific rate in 1999 from Fiji to Los Angeles was $2.10/kg (Baquero 1999).
- There is direct service to Taipei via Far East Transport (rates not known).

Appendix 2. List of Contacts & Acknowledgements

Shinji Chibana	Owner, Palau Biotech
Adalbert Eledui	Director, Department of Conservation and Law Enforcement, Koror State
Johnny Gibbons	Principal, Koror live reef fish export operation
Michael Guilbeaux	Community Conservation Network (working with Hatohobei State)
Hideyuki Hoshina	Cooperative Coordinator, Palau Ministry of Commerce and Trade
Noah Idechong	Former Executive Director, Palau Conservation Society and currently the Delegate for Ngiwal State in the Palau National Congress
Theofanes Isamu	Chief, Palau Division of Marine Resources
Eddie Liu	Principal, northern reefs live reef fish export operation
Santos Olikong	Principal, Palau Fishing Industry (Ngatpang-based live reef fish operation)
Thomas Patris	Principal, Helen Reef live reef fish export operation
Larry Sharron	Manager, Belau Aquaculture
Jennifer Sugiyama	Owner, Belau Aquaculture
Victor Yano	Owner, Belau Aquaculture

The author would like to acknowledge that some of the information used in this report was collected while employed by the Division of Marine Resources (Bureau of Natural Resources and Development) and later while employed by the Palau Conservation Society.

The draft report was kindly reviewed by Robert Johannes, Andrew Smith, Theofanes Isamu, Larry Sharron and edited by Alex Sheshunoff.

Appendix 3. The Nature Conservancy Strategy for the Live Reef Fish Trade

The Nature Conservancy's draft Five-Year Asia Pacific Region Strategic Plan (2001-2005) calls for action regarding the live reef fish trade in the context of reducing destructive fishing practices. The strategy is focused "on live food fish issues and not on the aquarium trade, with input to the latter restricted to representation on the Board of the Marine Aquarium Council." The strategy for the food fish trade includes components that would: 1) through technology and policy, shift the supply from wild to cultured product, 2) encourage viable and sustainable capture fisheries through country-specific policy and management, and 3) regulate the trade through international agreement, particularly through APEC. It is emphasized in the strategy that TNC's interest in the trade is motivated and guided primarily by the impact of the trade on biodiversity, not by issues of fishery sustainability.

With regard to policy and management in Pacific Island source countries such as Palau, the TNC strategy calls for: 1) the development and testing of legal mechanisms to improve co-management, local tenure, and traditional and innovative management systems; 2) the development of generic licensing agreements and management standards that could be adopted by specific countries; and 3) the provision of management advice to specific countries.

Year-2001 goals for the Pacific Coastal and Marine Program include preparation of a review of the live reef fish trade in Palau and the development of strategies for effecting action by Palau's state and national governments. Another goal is aimed at improving the protection and management of spawning aggregating sites in the region.

Appendix 4. Contract Terms of Reference

This assessment was one of four tasks completed under Contract Number APRO/GRAH011300:

"In consultation with the Coastal/Marine Management Specialist, prepare a report on the issues, history and current situation of the live reef fish (both food and aquarium fish) trade in Palau. Provide recommendations on future actions, including, but not limited to, policy, management, legislation, awareness, research and monitoring, aggregation sites and marine protected areas."