Aquarium Fishes and their Collection in the Great Barrier Reef Region

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Great Barrier Reef Marine Park Authority

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GREAT BARRIER REEF MARINE PARK AUTHORITY
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SUMMARY

The size and nature of the aquarium fish industry in the Great Barrier Reef Region makes it both economically and ecologically important. The industry is expanding fast, yet little information is available. Existing information on the operation of the industry and the biology of target species has been collated, and has shown that:

Both locally and internationally, the Great Barrier Reef aquarium fish industry remains relatively underdeveloped.

In 1985, 10 commercial operators are known to collect from Capricornia section reefs, Up to 16 commercial operators are known to collect from reefs in the Cairns Section, and about 10 from Townsville and Mackay reefs.

An unknown number of amateurs collect throughout the Great Barrier Reef Region.

The information on numbers of target species is insufficient to distinguish between natural population fluctuations, and fluctuation due to collecting.

Potential areas of conflict exist but further research is required to identify them.

KEYWODRDS: aquarium fish, collecting, GBR, management, impacts

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1. INTRODUCTION

The aquarium fish industry is reported to be the world's largest fishery with annual retail sales (including both fish and associated equipment such as pumps, tanks, food and drugs) of $4 billion in 1971 (McKay, 1977). The value in Australia in 1973 was estimated to be $80 million annually (McKay, 1977), although marine aquarium fishes probably do not contribute greatly to this figure, they constitute a small but increasing fraction of the total number of imported fishes (McKay, pers comm.). Of the estimated 2 500 species of aquarium fish recorded from Australia, nearly 90 percent are marine, and most of these are from the Great Barrier Reef (McKay, 1977).

Rapid growth of the industry over the last 15 years is due largely to an improvement in airline services and modern methods of fish transportation (McKay, 1977). Although still in its infancy, the industry's rapidly expanding nature makes it of considerable potential economic significance to Australia.

In addition to being economically significant, the industry may be of ecological importance. The Great Barrier Reef is one of the most complex ecosystems known to man, and is also one of the least understood. The removal of reef fish for the marine aquarium trade has unknown effects on the ecosystem of the reef. Little has been documented on tropical marine aquarium fish collecting in the Great Barrier Reef Region (GBRR) and very little is known about its effects on reef fish populations.

There are no detailed, long term records of species, locations, or numbers of fish collected. As a result, there is little integrated knowlege about the immediate or future effects of the collection of fishes on the natural fish populations.

There is also very little published information on reproduction, larval dispersal, recruitment, life histories and natural mortality of aquarium species. Similarly, there is little information about whether the lifespan of some marine species in captivity justifies their capture for aquarium purposes.

Due to the economic, as well as ecological, significance of this industry, there are differing views concerning management strategies which might be imposed on the industry. Some of those concerned with the ecology of the reef want the collection of aquarium fish restricted, whilst those relying on the industry for a living want collecting to continue unrestricted.

Until scientific evidence is obtained regarding the effects of aquarium fish collecting on the reef ecosystem, management decisions should take into account both the livelihood of the collector and the continued well-being of the reef. This is difficult to achieve when so little is known of the industry. It is necessary to assess the status of aquarium fishes in the GBRR in order to determine the management measures required, if any, an evaluation of the industry and its effects on the GBRR.

This report considers the operation of the industry, current regulation of the industry, known biology of important aquarium species, as well as presenting discussion regarding regulation of aquarium fish collecting.

2. OPERATION OF THE INDUSTRY

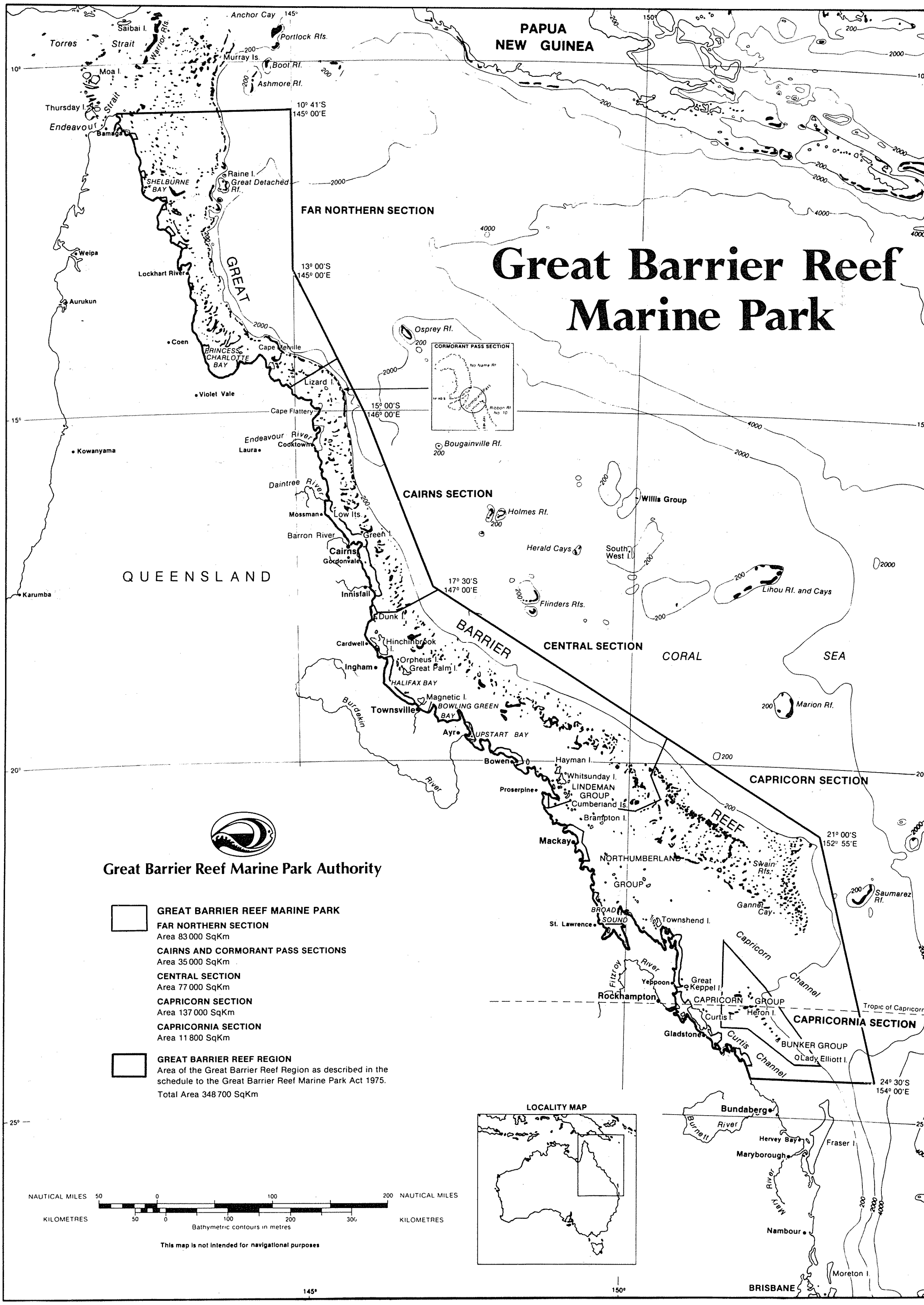
No consistent long term records are available of numbers and species of fish captured for the aquarium trade. The only information recorded at the present time has been voluntarily supplied by collectors. However, because not all collectors supply information, an exact record of the number, location and species of fish captured is not available. The total number of fishes captured obviously depends upon the number of collectors, the number of trips made by each collector and environmental factors such as weather and turbidity.

The precise number of collectors is unknown. This is because; until 1985 commercial collectors could operate under master fishermans licences, some collectors operate without permits, and, to date, amateur collectors do not require a permit in unzoned areas of the Great Barrier Reef Marine Park. Available records however, indicate that at present there are a small number of amateur collectors spread through the GBRR, approximately 40 commercial operations in the Great Barrier Reef Marine Park; about 10 in the Capricornia Section of the Park, up to 16 commercial operations in the Cairns and Far Northern Sections, and approximately 10 operators in the Townsville and Mackay areas.

2.1 Collecting areas

The most intensive commercial collection from the Great Barrier Reef occurs on reefs out from Cairns, although the fringing reefs of the Keppel Islands and reefs in the Capricornia Section are also important collection sites (Figure 1). This is due to the proximity of these reefs to populated areas and the mainland, as well as the numbers and variety of fish present. Most operators collect from reefs near their base, as large runabouts (5 to 6m in length) appear to be the preferred mode of access, although increases in collecting activity are encouraging some operators into larger vessels.

Figure 1. The Great Barrier Reef Marine Park.



In the Cairns Section, reefs subject to heaviest collection are Michaelmas Reef, Upolo Reef and the flats of Arlington Reef. Other reported collecting sites in the Cairns Section vary, depending on the base for the collecting operation:

- Ex Port Douglas - Rudder, Undine, Batt, Tongue and Saint Crispin reefs.
- Ex Cairns - Arlington, Euston, Oyster, Sandy, Michaelmas, Hastings, Nicholas, Hope, Tetford, Moore, Elford, Sudbury, Spier, Franklands Island, St. Crispin and Agincourt reefs.
- Ex Mission Beach - Eddy reef.

In the Capricornia Section of the Great Barrier Reef Marine Park, most reefs except Heron and Wistari are believed to have been long-term collecting areas for aquarium fishes. Collection is known to have occurred at North, Wilson, Tryon and North West Reefs in the northern parts of the Section and at Llewellyn, Boult, Hoskyn, Fairfax and Lady Musgrave Island Reefs of the Bunker Group in the southern parts of the section. Collecting at Heron, Wistari, Wreck, Llewllyn and One Tree is not permitted under the Capricornia Zoning Plan and, currently two other reefs (Boult and North) are closed as Replenishment Areas.

2.2 Techniques of fish collecting

2.2.1 Breathing systems

Collecting fishes without damaging them is both time consuming and hard work. The use of underwater breathing apparatus makes the task somewhat easier. 'Hookah' and SCUBA equipment are both used by collectors, although some collectors still snorkel to catch fish in very shallow water.

Collecting is usually carried out in relatively shallow water, because of the limited time the diver can spend on the bottom and the need to decompress fish as they are brought to the surface.

2.2.2 Nets

The most popular apparatus for aquarium fish collection in the GBRR is a fence or barrier net. It is generally made of nylon monofilament, with a mesh size of roughly 12 to 18mm. The fence net is usually 9 to 10m long with a 1 to 2m drop. These dimensions may vary, and may partly depend on the type of breathing apparatus the collector is using. Small lead weights along the bottom of the net (lead line) keep the net negatively buoyant while rubber or plastic floats along the top (float line) keep the net upright. These nets do not gill the fish, but the small size of the mesh contains them by creating a barrier.

The net is set up in a crescent or V-shaped arrangement in the desired area and the collector positions himself so that the fish are between him and the net. The diver swims slowly toward the net ushering, without alarming, the fish toward the net. Between 2 and 3m from the net, the diver moves in quickly and hopefully traps the fish against the fence net with a small hand-net. With this approach, only one or two fish are caught in each 'run' at the fence net, as the fish are only impeded momentarily before they speed off in all directions. However, the efficiency of the system is easily increased by setting the fence net up in a horseshoe shape and herding the fish in. The net is then closed to form a ring and the required fishes are selected and then collected with a hand net.

2.2.3 Hooks and lines

Small barbless hooks have been used with some success to catch the larger aquarium fishes. This method may damage the fish and may result in secondary infection, so care must be taken to ensure survival. These fishes are more commonly used in large display aquaria rather than by the hobbyist.

2.2.4 Chemicals and expolsives

There is no evidence that explosives are used in the Great Barrier Reef Region for the collection of aquarium fishes, although the practice occurs in other parts of the world (Lubbock and Polunin, 1975). Chemicals such as quinaldine and rotenone with potassium permanganate, chlorinated lime or methylene blue used as a detoxicant, are known to be in use (Robinson, 1981; Bellwood, 1981). Under the Queensland Fisheries Act, 1976; prior written permission from the Minister is required for the use of either explosives or chemicals.

2.2.5 Transportation

Once fish have been collected, the collector transfers them to a holding bucket which may be on a weighted line hanging from the boat or by his side. Upon returning to the boat, the diver will raise the bucket and, depending on the depth of collection, the fish may be decompressed on the trip to the surface. Fish decompression is a factor often overlooked by collectors, and failure to decompress fish can lead to incresed mortalities. As a result, a number of different procedures have been proposed (Daigle, 1978; Siri and Barnett, 1980).

For transport from the colecting site, the fishes are kept in either a specially designed holding tank or a plastic garbage bin. Sea water is fed into the holding tank and, in some cases, sophisticated recirculating units are used to help maintain the fishes. Small, battery operated oxygenating units may be used in some cases, and some collectors use air remaining in SCUBA cylinders.

The collector usually has his warehouse close to the docks or other major transport facilities to minimize handling and time in transit. Holding tanks in warehouses are usually large and have elaborate water quality control devices, including different types of filters and sterilizers.

If fish are to be transported long distances; interstate or overseas, they must be specially packaged. Double or triple polyethylene bags are used, one fish to each bag, and they are inflated with oxygen at a water:oxygen ratio of 1:3. The plastic bags are usually transported in cardboard cartons. This method appears suitable for up to 24 hours (Daigle, 1978).

For fish to survive in captivity, many factors must be considered, including temperature, salinity, pH, turbidity and diet. Hardy fish may survive for up to 10 years in a home aquarium if well looked after. Fragile fishes may not cope with life in an aquarium and if the fish do not die shortly after being introduced they may gradually lose condition and succumb to diseases. Little is documented on the longevity of aquarium fishes in captivity (or, indeed, under natural conditions), and most of the information that is available comes from collectors and public aquaria. The varying details imply that both the maintenance and collection methods are decisive factors. Many collectors prefer juvenile stock as their survival rate is likely to be higher. This is important as the collection of juvenile individuals may prevent the depletion of the natural breeding population and may allow for quicker recovery of collected species.

Longevity figures for some aquarium species which have survived for lengthy periods in Taronga Park Zoo Aquarium have been supplied by John West, Senior Aquarium Keeper. The figures are presented in Table 1.

Table 1. Longevity records for some aquarium species of more than five years of age (J. West, _pers comm._, 1981).

Common Name	Scientific Name	Total Years
Butterfly Cod	_Pterois volitans_	6
Longnose Butterfly fish	_Forcipiger flavissimus_	5
Banner fish	_Heniochus acuminatus_	8
Black Backed Butterfly Cod	_Chaetodon melanotus_	6
Threadfin Butterfly fish	_Chaetodon auriga_	6
Dusky Butterfly fish	_Chaetodon flavirostris_	5
Moorish Idol	_Zanclus canescens_	6
White Spot Humbug	_Dascyllus trimaculatus_	6
Blue Pullers	_Chromis caeruleus_	6
Cleaner Wrasse	_Labroides dimidiatus_	6
Moon Wrasse	_Thalassoma lunare_	5
Blue Striped Surgeon	_Acanthurus bleckeri_	5
White Blotched Triggerfish	_Balistoides conspicillum_	13
Black Triggerfish	_Odunus niger_	5

2.3 Economics of collecting

A great number of species are presently collected (Appendix I) however, the figures supplied by collectors concerning the numbers of fish collected vary greatly. For example, two collectors operating in the Capricornia Section both make 1 or 2 trips of approximately 2 weeks duration each year and report catching between 20 and 30 fish per day. A fairly substantial operation in the Cairns Section collects up to 200 to 300 damsels (Pomacentridae) and 100 to 150 Chaetodons per diver. The operation reportedly collects in the vicinity of 25 000 fish per year and estimates of mortality are approximately 1 percent.

If these figures are accurate, it could be calculated that between 3 000 and 6 000 specimens per week may be sent out of the Cairns area. The average price for a fish is approximately \$3.50, (ranging from \$0.70 to \$40) which would mean that this industry may generate between \$500 000 and \$1 million annually (in the Cairns district alone), from the sale of fish to other parts of Australia and overseas.

The overseas trade in marine aquarium fishes is still largely undeveloped, as is the potential of the local market. This is evident when one considers that Australia is one of the main aquarium fish importers. In 1975 Australia imported 1 601 boxes of marine aquarium fish from the Philippines (each box containing between 30 and 50 fish) with an estimated value of approximately \$20 000. Australia also imports marine aquarium fish from Singapore, Fiji and Indonesia, although the extent of importing is unknown.

At present, about 80 percent of marine aquarium fish are collected from the Philippines, with a further 16 percent from Hawaii and Florida. Australia's contribution to the world trade is currently negligible (Siri and Barnett, 1980).

With increasing freight charges, it has been suggested that the local industry may become more economically viable and may expand and capture some of the import market. The Australian export of marine aquarium fish is also minimal. However, Lubbock and Polunin (1975) list Australia as an exporter of marine aquarium fish. There is currently an overseas market for species endemic to Australia which could be greatly expanded. At present, the export of these species is almost entirely limited to America and West Germany.

Species included are:

Harlequin Tuskfish (*Choerodon fasciatus*)
Black Angel (*Chaetodontoplus personifer*)
Rainfords Butterfly (*Chaetodon rainfordi*)
Scribbled Angel (*Chaetodontoplus duboulayi*)

3. CURRENT REGULATION OF COLLECTING

Different license/permit conditions exist, depending on whether the collection is for commercial or recreational purposes, and whether the collection of aquarium fish is occuring in zoned areas of the Great Barrier Reef Marine Park or not. Permits, licences, and Queensland and Commonwealth legislation for commercial collectors and vessels are currently (1986) being revised.

3.1 Professional collectors:

- unzoned areas of the Marine Park

    Master Fishermans licence (if collection of aquarium fish is only part of the commercial operation).

    Fish and Marine Products Permit ($58 per permit) (where aquarium fish are collected exclusively).

    Commercial Fishing Vessel licence.

    Assistant Fishermans licence - for offsiders (needed only on the Master Fishermans Licence as the Marine Products Permit covers more than one person).

    Commonwealth Licences - required when collecting in Commonwealth waters (rarely issued).

    separate licences may also be required for collection of coral and other sedimentary organisms.

The above licences are issued through the Queensland Fisheries Management Authority (QFMA) and the Queensland Department of Primary Industries (QDPI); some details of collection are required before licencing.

- zoned areas of the Marine Park
  (Cairns, Far Northern and Capricornia Sections)
    - General Use 'A' and 'B' Zones:

        licences/Permits as applicable above, plus
        GBRMPA Collecting Permit (through Q.NPWS)
    - Other Zones:

        no recreational or commercial collection permitted.

3.2 Amateur collectors:

- unzoned areas of the Marine Park

  no licences or permits required from either QFMA or GBRMPA

- zoned areas of the Marine Park

  (Cairns, Far Northern and Capricornia Sections)

  - General Use 'A' and 'B' Zones:

    licences/Permits as applicable above

    GBRMPA Collection Permit (through Q.NPWS)

  - Other Zones:

    no collection permitted (except for scientific purposes and then only with a GBRMPA Research Permit suitably endorsed)

These regulations have been instigated to ensure conservation of the reef while allowing reasonable collecting and to separate conflicts of use. The scientific evidence regarding limits on numbers collected to prevent overexploitation is currently inconclusive.

4. KNOWN BIOLOGY OF POTENTIAL AQUARIUM FISH AND IMPLICATIONS POSED BY COLLECTING

This section of the report considers the possible implications collection may have on the structure of reef fish communities and on individual species themselves. Despite the greatly increased attention to coral reefs shown by ecologists in the past decade, the questions tackled have been primarily community level ones. The basic demographic process in possible target species have been largely neglected. However, some of the factors that maintain the diversity of reef communities are thought to be:

habitat variety;
variable recruitment;
pelagic larvae leading to dispersion;
large numbers of larvae;
and, extended breeding seasons (Reese, 1973; Sale, 1975).

In order to evaluate the impact of collection on reef communities, some knowledge of both community structure and recruitment must be sought.

4.1 Community structure

To date, the structural nature of the communities has been interpreted in two different ways. Depending upon the system envisaged, different consequences due to collection might be predicted.

4.1.1 Order theory

Very simply this states that the structure of the community is maintained by interactive communities made up of species specializing in different ways, thus partitioning the resources of the environment (Anderson et al., 1981). In such a system, collecting might remove a species thus vacating a niche. This niche may then be re-occupied by a member of the same species, the total process having little effect on the equilibrium of the reef.

4.1.2 Chaos theory

This states that the structure of the community is maintained by chance colonization by species with broad and largely overlapping requirements, which do not interact with each other sufficently to shape the community being formed. (Sale and Dybdahl, 1975). In this system the vacating of a niche through the collection of a particular species would not necessarily lead to its reoccupation by a member of the same species. This could have more serious consequences on the diversity within reef systems.

Neither theory has been unequivocally confirmed, and the possible effects from fish collecting are necessarily hypothetical. In 'order' systems, for instance, there is no guarantee that a niche vacated by a particular species will be re-occupied by a member of the same species. Likewise in a 'chaos' system there maybe so much 'noise' that it is hard to envisage any deleterious effects from low levels of fish collecting. From the available evidence compiled from fish collectors and the research projects which have addressed the problem, the observed effects of collection seem to be negligible (Nolan, 1978; Russ, 1984).

4.2 Recruitment

As with community structure, until recently little work had been undertaken on recruitment. Two theories have been proposed.

4.2.1 Resource limited recruitment

In this system, any space that becomes available is refilled from a saturated pool of larvae, the limiting factor therefore being space (Sale, 1975). In such a system the predicted effects of collecting would be short-term and minor.

4.2.2 Recruitment limited population

In contrast to the first recruitment theory, this suggests that the number of available recruits, not the resource, is the limiting factor (Robertson et al., 1981). In such a system, the potential effects from collecting could be a reduction in that year class, thus producing a more serious reduction in the abundance of that species at that location until further recruitment occurred. Long-term effects are not really known.

As with 'community structure' these are hypothetical situations based upon only a few relevant research projects. A fuller understanding of effects of collecting on both community structure and recruitment requires greater information than we now have concerning accuracy of sampling methods, reproductive seasons, fecundity, larval survival and behaviour, longevity of reef fishes and species interactions. Information on events at the moment of larval settlement on the reef will be crucial to our further understanding of reef fish communities.

In addition to obtaining long-term monitoring studies will be useful to obtain some idea of natural fluctuations in the given areas, particularly considering that reef fish communities are often thought to exist in a permanent state of disequilibrium (Connell, 1978; Sale, 1980; Doherty, pers comm.). The degree and determinants of natural fluctuations must be ascertained before fluctuations in reef fish communities due to aquarium fish collecting, or any other external cause, can be established.

5. REVIEW OF POTENTIAL AREAS OF CONFLICT WITH SUGGESTED SOLUTIONS AND PROPOSED RESEARCH PROGRAMS

Some research has been carried out on the effect of collecting specific aquarium fishes on reef populations, but this discussion will be limited to the areas of concern which have most relevance to the Great Barrier Reef.

5.1 Areas of conflict

5.1.1 Effects on target species

- Collection in certain areas may deplete numbers of a species in a localised region (Walsh, 1978). Lubbock and Polunin (1975) cite examples of supposed extinctions along the Sri Lankan and Kenyan coasts where collection has been confined to small areas.

- Collection of fish from accessible depth ranges may deplete numbers in this range. Although they may still be common at greater depths, to the diver and sightseer however, the species is as good as extinct (Walsh, 1978). Local depletion of Blue Tang (*Paracanthurus hepatus*) has been reported at Arlington Reef as a result of collection (Ian Croll, *pers comm.*).

- Even though the diversity of fish in reef ecosystems is great, not all species are particularly abundant and some may be greatly depleted in abundance by collection. 35 percent of the Hawaiian aquarium fish catch is composed of species rated between 'scarce' and 'rare' (Walsh, 1978).

- de Boer (1981) voiced concern over the collection of species that undergo a sex change. He used an example *Gamma loreto*, a protogynous species (changes from female to male). If the larger fish were caught continually and there was no compensating reduction in the size of sex change, the population would be all female, resulting in no breeding. The same may well apply to protandrous species (those which change from male to female).

5.1.2 Effects on the reef community

- Destruction of shelter while collecting (Walsh, 1978) will decrease utilizable reef fish living space. This may lead to a reduction in the number of reef fish (and other organisms).

- de Boer (1981) was concerned that removal of cleaner fish may result in an increase in fish parasites on previously 'clean' fish, with possible deleterious effects.

- Removal of herbivorous species may lead to a significant increase in algal coverage, which may result in decreased settlement of coral planulae, hence reduced coral coverage and less habitat for fish (de Boer, 1981; Dart *in* Lubbock and Polunin, 1975).

- The wrasse (*Cheilinus undluatus*), Pufferfish (*Arothron hispidus*) and Tiggerfish (*Balistoides vindiscens* prey upon *Acanthaster planci* (Crown of thorns starfish) (Roads and Ormond *in* Lubbock and Polunin, 1975).

- Collection of aquarium fish may disadvantage predator species if numbers of the small reef fish are severely depleted. *Abudeduf spp.*, *Acanthurus spp.* and *Pomacentrus spp.* have been found in the stomach contents of coral trout (Goeden, 1978; Choat, 1968), although coral trout appear to be opportunistic feeders. The relative absence of these and other large predatory fish may affect reproductive strategies and density dependant aspects of the life histories of prey fishes such as the smaller aquarium fishes, although there is no information to support or refute this view (Russ, 1984).

- Although illegal, the use of chemicals to capture aquarium fish in the Great Barrier Reef Region is reported to occur, but the extent of this is unknown (McKay, pers comm.). Cyanide is reported to be employed widely in the Philippines, whilst in other countries, both overseas and in Australia, the most widely used chemicals are quinaldine and rotenone (Robinson, 1981). Jaap and Wheaton (1975) report that there is minimal or no long-term damage to coral exposed to test quinaldine solution, however the commercial rotenone preparation causes severe damage to coral colonies, killing many species. Cyanide, although having an anaesthetizing effect on fish, lingers in the fish's digestive system and erodes the intestinal lining (Bellwood, 1981), premature death often resulting. To date its use has not been reported in the GBRR.

5.2 Suggested solutions

- Creation of artificial habitats/reefs in some areas (Nolan, 1978) in order to increase living space and thus abundance of reef fish.

- Species of reef fish which are particularly rare may require total protection (Walsh, 1978; Lubbock and Polunin, 1975) from collecting pressures.

- A review of collecting techniques and elimination of those harmful to the reef environment (Walsh, 1978; Lubbock and Polunin, 1975).

- Close heavily collected areas periodically in order to permit revitalization of collected stocks (Walsh, 1978). This idea is similar to the Temporary Reserve idea (Lubbock and Polunin, 1975; Siri and Barnett, 1980) whereby areas of permitted collection are rotated continually.

- Control over numbers of collectors in an area and over numbers and types of fish collected (Walsh, 1978; de Boer, 1981).

- The declaration of sanctuary areas (Randall, 1978; Taylor, 1978; Siri and Barnett, 1980; Nolan, 1978) would have many advantageous characteristics in addition to the protection of reef fish species within the sanctuary confines:

  - enhance collecting in adjacent areas through larval production

  - provide study areas for comparison.

- Lubbock and Polunin (1975) voiced concern over the wastage between capture and retail distribution, due to lack of control over exporters and importers, resulting in inexperience entering the trade. This inexperience results in unnecessarily high mortality which is an inefficient utilization of the natural resource. They feel that competition and free trade are not necessarily beneficial to the coral reef fish trade and that such competition leads to unnecessary exploitation to compensate for the inefficiency of exporters and importers. The following proposals were made:

  - requirements of proficiency in the trade (licences)

  - catch reports

  - in countries bordering temperate/tropical seas, aquarists should be made aware of the ecological dangers of releasing exotic species.

- Mariculture, considered below in some detail, involves a new approach to the aquarium fish trade; a farming approach rather than a hunting approach as presently practised.

Mariculture is a recent marketing development in the marine aquarium fish industry and is in its infancy compared to its freshwater counterpart. The development of this technique offers an alternative to, but not a replacement for, collecting from the wild. It provides some control over the product, which may be managed more efficiently, thus providing a higher yield. Through genetic selection, faster growing and more tolerant varieties may be produced. While the prices are lower per unit, a larger volume is possible, along with the hybrids and varieties which increase the desirability and demand for the product (Madden, 1978).

Very few marine aquarium fishes have been bred sucessfully in captivity and there seems to have been little documented research on rearing of coral reef fishes. While a number of fishes have been observed to spawn in aquaria, filtration may destroy eggs unless precautions are taken.

Other limitations have been the difficulty in keeping marine fish in conditions good enough to allow gonad development and spawning, the specialised requirements of larval fish for food and environment, and a proclivity for disease in captive fish (Moe, 1981).

Madden (1978), of the Oceanic Institute of Hawaii reports that generally marine fish will not spawn in captivity and spawning must be manipulated through environmental changes and/or hormone injections.

Fish that lay demersal eggs (on the substrate) are better prospects for mariculture since the young do not require pelagic conditions of food and space, which are difficult to reproduce in the aquaria (Siri and Barnett, 1980). In some instances it will not be possible, practical or economical to breed certain species, and collecting from the wild will still be necessary (Madden, 1978). Already however, there has been some degree of success in the mariculture of some aquarium fish:

- The White Tailed Puller (*Acanthochromis polyacanthus*) broods it's eggs and breeds successfully in aquaria (Watson, *pers comm.*).

- Some successful breeding of clownfishes in Germany (*Amphiprion akailopisas* and *A. ephippium*) and Australia has apparently been achieved (Nequebauer *in* Allen, 1975; McKay, *pers comm.*).

- Clownfish (*Amphiprion spp.*) have also been hatched at Taronga Zoological Aquarium (West, *pers comm.*).

- The Mandarin fish (*Synchiropus splendidus*) and Australian Orange Tail Blue Damsel (*Glyphidodontops hemicyaneus*) are also believed to have spawned in captivity (Brown, *pers comm.*).

- Martin Moe Jnr, from Aqualifi Research Corporation in Florida has been involved with the development of culturing ornamental fish since the early 1970's and presently markets small numbers of cultured clownfish (*Amphiprion*), Neon Gobies (*Gobiosoma oceanops*), angelfish (*Pomacanthus*) and a hybrid angelfish. He has also spawned and reared to the juvenile stage a number of other species as listed in Table 2.

Table 2. Species of fish reared to the juvenile stage under artificial conditions by M. Moe, Jnr.

Scientific Name	Common Name
Amphiprion akallopisos	Skunk Clownfish
A. chrysopterus	Gold Fin Clownfish
A. clarkii	Clarkii Clownfish
A. ephippium	Black Backed Clownfish
A. frenatus	Brindled Clownfish
A. melanopus	Black Clownfish
A. ocellaris	Orange Clownfish
A. percula	Percula Clownfish
A. perideraion	Pink Skunk Clownfish
A. polymnus	White Saddled Clownfish
A. rubrocinctus	Richardson's Clownfish
A. sandaracinos	Allen's Clownfish
A. tricinctus	Three Band Clownfish
Premnas biaculeatus	Maroon Clownfish
Gramma loreto	Royal Gramma
Apogon nematopterus	Cardinal fish
Trachinotus carolinus	Florida Pompano
Lutjanus griseus	Grey Snapper
Anisotremus virginicus	Parkfish
Haemulon plumieri	White Grunt
Equetus acuminatus	High-hat
E. lanceolatus	Jackknife fish
Chaetodipterus faber	Atlantic Spadefish
Pomacanthus arcuatus	Grey Angelfish
P. paru	French Angelfish
Abudefduf saxatilis	Sergeant Major (Black)
Hypsypops rubioundus	Garibaldi
Pomacentras flavicauda	Yellowtail Damsel (Jewel fish)
Lachnolaimus maximus	Hogfish
Opistognathus aurifrons	Yellowhead Jawfish
Gobiosomus multifasciatum	Greenband Goby
G. evelynae	Sharknosed Goby
G. oceanops	Neon Goby

Gobiesox strumosus	Skilletfish
Hippocampus erectus	Lined Seahorse
H. zosterae	Dwarf Seahorse
Sphoeroides maculatus	Northern Puffer

In the short term, culture of tropical fish will not be widely adopted, as it is currently not competitive with collecting and there is little economic incentive to do so because of imports, and the preliminary research required. Thus it may fill only an alternative role, when divers cannot collect either through inclement weather or due to other causes. In the long term however, raising ornamentals from the egg stage may prove to provide less expensive and healthier specimens, while reducing the pressure on heavily collected reef areas.

5.3 Proposed research programs

One of the primary themes of this report was to indicate those areas where knowledge is lacking. Considered below are appropriate research programs that may fill this gap in knowledge and allow future management decisions to be made regarding aquarium fish collecting.

5.3.1 Biological studies

- Basic biology and population dynamics of individual species:

  including distribution, larval duration, growth, age at maturity, mortality, fecundity, recruitment, life-histories, territoriality, home ranges and population densities.

- Effects of collecting on target and non-target communities.

- Environmental effects on individual species:
  effects of temperature and salinity changes as well as other biotic and abiotic factors.

- Mariculture:
  breeding of stock aquarium fishes.

- Survival in captivity:
  longevity - does this differ from the natural environment.

Such biological information is specific however, to the species studies and to the region where the study was conducted. Hence, it will be a long time before a thorough knowledge of the detailed effects of aquarium fish collecting on an environment may be obtained.

5.3.2 Economics of the industry

- The collectors:
  what is the value of locally caught fish (compared with the value of other fisheries, imported aquarium fishes, cost of aquarium fish research etc.).

- The industry:
  import costs and values
  wholesale/retail sales
  potential for Australian caught fish in market terms.

This information will indicate how important the industry is in economic terms and will give some hint as to the extent of collection and the possible future growth in the industry.

5.3.3 Fishing activities

- The fishery:
  - catch and effort data
  - localities collected from
  - fishing methods.

- Environmental effects:
  - what damage is done by fishing activities compare with anchor damage, tourists, *Acanthaster planci*, cyclones, chemicals.

As biological information will be obtained only very slowly, the abovementioned information would provide useful guidelines for the monitoring of the industry in the meantime. This type of information might best be collected by introducing a log book. This could enable the collection of useful, long-term data, allowing the monitoring of individual species at specific reefs.

6. DISCUSSION

This report has outlined the nature of the aquarium fish industry in the Great Barrier Reef Region as it is presently understood.

It is readily apparent that tropical reef fisheries management strategies do not have an equivalent theoretical basis to temperate water fisheries. The absence of stable equilibrium populations and pelagic larvae (Johannes, 1978), suggests that population fluctuations may be a normal occurrence. Control measures seeking to maintain an equilibrium population would therefore be difficult to justify and might be extremely difficult to implement. It is therefore necessary to evaluate the 'normal' range of fluctuation to determine whether deviations exceed this range.

The collection of base data appears to be a logical step in gathering information on collecting in the GBRR. With the prospect of growth in the Australian tropical marine aquarium fish collecting industry, research should be undertaken to ensure the successful management of the industry in the future.

The basic data requirements to enable directed management decisions to be made are a detailing of the catch with associated effort, indices of abundance, age composition and species identification (Larkin, 1981). Without such data it is impossible to say whether any future regulation of aquarium fish collecting is required in the Great Barrier Reef Marine Park. Great Barrier Reef Marine Park Zones, (Marine National Park 'A' and 'B' Zones; Marine National Park Buffer Zones, Scientific Research Zones, and Preservation Zones), in which recreational or commercial aquarium fish collecting is not permitted, will ensure that certain areas are left untouched, but will also provide comparisons for those zones in which collecting is permitted.

Future research into aquarium fish collecting should provide information on specific reefs, most importantly, those reefs which are being most heavily collected. With such information, the Great Barrier Reef Marine Park Authority and other agencies will be able to make sensible, data-based management decisions regarding aquarium fish collecting and the well being of the reef.

7. CONCLUSIONS

- The aquarium fish collecting industry is expanding but still underdeveloped (locally and internationally).

- Aquarium fish are imported into Australia principally from the Philippines, but also from Singapore, Fiji and Indonesia. Many of the species involved also occur on the Great Barrier Reef.

- Some aquarium species endemic to Australia are exported, although this is limited almost entirely to America and West Germany.

- There are known to be approximately 16 commercial collectors in the Far North and Cairns Sections, about 10 operating from the Townsville and Mackay areas, and 10 in the Capricorn and Capricornia Sections. An unknown number of amateur collectors also operate in the Great Barrier Reef Region.

- Some work on the biology of target species has been undertaken but the results are inconclusive. Natural population fluctuations are observed and detailed studies must be undertaken to demonstrate the differences (if any) between the effects of natural variation and collection.

- To refine management policy and regulations with respect to the industry and reef conservation, more information is essential.

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APPENDIX I.
A PRELIMINARY LIST OF FISHES SUITABLE FOR THE AQUARIUM FISH TRADE.

ACANTHURIDAE: [Surgeonfishes]

Acanthurus dussumierei
Acanthurus glaucoporeius
Acanthurus lineatus
Acanthurus nigrofuscus
Acanthurus olivaceous
Acanthurus pyroferus
Acanthurus triostegus
Acanthurus xanthopterus
Naso annulatus
Naso lituratus
Naso unicornis
Paracanthurus hepotus
Zebrasoma scopas
Zebrasoma veliferum

APOGONIDAE:

Apogon sp.

BALISTIDAE: [Triggerfishes]

Balistapus undulatus
Bilistoides niger
Mehichthys vidua
Pseudobalistes fuscus
Rhinecanthus aculeatus
Rhinecanthus echarpe (Balistapus rectangulus)
Rhinecanthus verrucosus
Sufflamen capistratus

BLENNIIDAE:

Exallias brevis

CHAETODONTIDAE:

Chaetodon aurefasciatus
Chaetodon auriga
Chaetodon baronessa (C. triangulum)
Chaetodon citrinellus
Chaetodon ephippium
Chaetodon flavirostris
Chaetodon guntheri
Chaetodon kleinii
Chaetodon lunula
Chaetodon melanotus

Chaetodon mertensii
Chaetodon ornatissimus
Chaetodon pelewensis
Chaetodon plebeius
Chaetodon rafflesi
Chaetodon rainfordi
Chaetodon reticulatus
Chaetodon semeion
Chaetodon meyeri
Chaetodon bennetti
Chaetodon speculum
Chaetodon tricinctus
Chaetodon trifascialis
Chaetodon trifasciatus
Chaetodon ulitensis (C. faleula)
Chaetodon unimaculatus
Chaetodon vagabundus
Chelman rostratus
Chelman mulleri
Chelmonops truncatus
Chelmonops howensis
Coradion altivelis
Coradion chrysozanus
Forcipiger flavissimus
Forcipiger longirostris
Hemitaurichthys zaster (H. polylepis)
Heniochus acuminatus
Heniochus chrysostomus (H. permutatus)
Heniochus singularius
Heniochus monoceros
Parachaetodon ocellatus

CIRRHITIDAE:

Cirrhitichthys aprinus
Paracirrhites forsteri

LABRIDAE: [Wrasses]

Anampses caeruleopunctatus
Anampses geographicus
Anampses meleagrides
Anampses neoguinaicus
Bodianus axillaris
Bodianus perditio
Cirrhilabrus equisitus
Cirrhilabrus laboutei
Choerodon fasciatus (Lienardella fasciata)
Coris aygula
Coris gaimardi
Coris pallida
Coris picta
Coris variegota
Gomphosus various

Halichoeres centriquadrus
Halichoeres nebulosa
Hemigymnus fasciata
Hemigymnus melapterus
Labroides dimidiatus
Labrichthys unilineata
Macropharyngodon meleagris
Macropharyngodon pardalis
Macropharyngodon choati
Pseudocheilinus hexataenia
Stethojulis bandanensis
Stethojulis axillaris
Stethojulis albivittata
Thalossoma janseni
Thalossoma harwicki
Thalossoma lutescens
Thalossoma lunare
Xyrichtys taeniourus
Hemipteronotus taeniurus

MONACANTHIDAE: [Leatherjackets]

Oxymonacanthus longirostris
Pervagor melanocephalus
Paraluteres pionurus
Canthescheria grandisquaius
Catherines howensis
Chaetoderma penicilligera

OSTRACIONTIDAE: [Boxfishes etc.]

Ostracion cubicus (O. tuberculatum)
Canthigaster sp.

POMACENTRIDAE: [Damselfish]

Acanthochromis polyacanthus
Amphiprion akindynos
Amphiprion clarkii
Amphiprion chrysopterus
Amphiprion latezonatus
Amphiprion melanopus
Amphiprion ocellaris
Amphiprion percula
Amphiprion perideraion
Premnas biculeatus
Abudeduf saxatilis
Abudeduf behni
Abudeduf cyaneus
Abudeduf melanopus
Chromis caeruleus
Chromis nitidus
Dascyllus aruanas
Dascyllus melanurus

Dascyllus reticulatus
Dascyllus trimaculatus
Pomacentrus coelestis
Pomacentrus sufflavus
Pomacentrus pavo
Amblyglyphidodom aureus

POMACANTHIDAE: [Angelfish]

Centropyge bicolor
Centropyge bispinosus
Centropyge flavicauda
Centropyge flavissima
Centrpyge heraldi
Centropyge tibicen
Centropyge fisheri
Centropyge vroliki
Chaetodontoplus conspicillatus
Chaetodontoplus duboulayi
Chaetodontoplus personifer
Pomacanthus (Euxiphipops) sexstriatus
Euxiphopops xanthometapon
Apolemichthys triamaculatus
Pomacanthus semicirculatus
Pygolites diacanthus
Genicanthus lamarcki
Pomanthus imepator

SCORPAENIDAE: [Scorpionfish, Lionfish etc.]

Dendrochirus zebra
Pterois antennata
Pterois lunulata
Pterois volitans

SERRANIDAE:

Anthias squamipinnis
Anthias huchti
Diploprion bifasciatum
Pseudochromis paccagnellae
Grammistes sexlineatus

PLATACIDAE: [Batfish]

Platax pinnatus
Platax orbicularis
Platax teira

LUTIANIDAE:

Macolor niger
Pentapodus setosus
Plectorhyncus chaetodontoides

Plectorhyncus punctatissimus

MISCELLANEOUS:

Blue Spotted Ray
Wobbegong Shark
Epaulette Shark
Anglerfish
Gobiid sp.
Monodactylid sp.
Canthigasterid sp.
Cleidopus sp.
Zanclus canescens
Lo vulpinus
Goatfish
Moray Eel

An annotated version of this listing is available on request from the Great Barrier Reef Marine Park Authority.