COMMERCIAL AQUARIUM FISH STOCK ASSESSMENT IN POHNPEI, FEDERATED STATES OF MICRONESIA

Prepared by the

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In as far as any reference in this report is or may be taken to be for potential commercial returns upon an investment in any existing, contemplated or future project, no responsibility is undertaken to any person, including SPC.

SUMMARY

In 2014, a member of the marine aquarium industry submitted an expression of interest to the Department of Resources and Development to establish a small high quality sustainable aquarium fish (and possibly aquaculture) export sector on Pohnpei. In response, the government of the Federated States of Micronesia submitted an official request for technical assistance to the Secretariat of the Pacific Community (SPC).

The current study sought to respond to this request by conducting underwater commercial surveys of marine aquarium resources around Pohnpei to update and complement work conducted by SPC together with Pohnpei's Office of Fisheries and Aquaculture (OFA) and the Conservation Society of Pohnpei in 2010, and determine whether a sustainable and viable business could operate from the island. Specific objectives included:

1. To identify aquarium fish species of value in Pohnpei and determine whether their abundance would allow for their sustainable collection and export;
2. Based on (1) determine sustainable and viable collection methods and rates; and
3. To develop management strategies and guidelines for the industry.

All surveys were conducted between the 25th September and 13th October 2014 at a total of 32 sites (including 3 at Ant (Ahnd) atoll). Surveyors spent a total of 13 days in the water covering outer reef and lagoon habitats.

While a few species were found to be available on the reef in commercial numbers, these were mostly low-value. Indeed, fish species that would support the development of a viable business (i.e., medium to high-value) were not recorded in sufficient numbers to support an industry. Non-competitive freight rates, limited freight space and other ecological and operational constraints presented further limitations. Most importantly, key species such as flame angelfish (*C. loricula*) and bartlett's anthias (*P. bartlettorum*) were found only at specific locations and in very low densities. *Centropyge loricula*, a species highly sought after and considered high-value on the marine aquarium trade market was identified as particularly vulnerable to collection given densities and distribution at both Pohnpei and Ant atoll.

In conclusion, all available information and survey findings do not support the development and establishment of a sustainable and/or viable industry on Pohnpei. We therefore do not recommend that Pohnpei and/or an operator invest time, finances or effort in developing such a fishery.

LIST OF ACRONYMS

CSP	Conservation Society of Pohnpei
DEA	Department of Economic Affairs[1]
DNLR	Department of Lands and Natural Resources
D-UVC	Distance based Underwater Visual Census
FSM	Federated States of Micronesia
KIRMA	Kosrae Island Resource Management Authority
MMME	Micronesia Management & Marketing Enterprises
MPA	Marine Protected Area
OFA	Office of Fisheries and Aquaculture
REA	Rapid Ecological Assessment
SPC	Secretariat of the Pacific Community

[1] Today synonymous with Department of Resource and Development

INTRODUCTION

Pohnpei, the capital state of the Federated States of Micronesia (FSM), is comprised of one main volcanic rock island, 8 small islets and five outlying atolls (Pingelap, Mokil, Sapwafik, Nukuoro, and Kapingamarangi), covering a total land area of 347 km^2. The main island consists of approximately 318 km^2 of land area and 178 km^2 of lagoon surrounded by just over 100 km of barrier reef.

A small marine aquarium trade industry used to run out of Pohnpei around 15 years ago. Unfortunately, information pertaining to its operation such as how long it was active for, how many staff it employed, or how many and what species it exported are not available.

In 2014, a marine aquarium export company by the name of Micronesia Management and Marketing Enterprises (MMME), which has been operational in Kosrae since 2005, expressed interest in potentially opening a collection and export facility in Pohnpei. In its evaluation of the submitted request, as well as discussions with the Secretariat of the Pacific Community (SPC) and the private sector, the Office of Fisheries and Aquaculture (OFA) established that the first step should be a commercial assessment of locally available resources of interest to the marine aquarium trade. In August 2014, SPC received an official request for technical assistance to determine whether Pohnpei's resources were abundant and diverse enough to allow for the development of a sustainable an economically viable aquarium export company.

Specifically, the letter asked for SPC to undertake the following:

1. "Consultations with State and National Government agencies;
2. Resource surveys and assessments of the abundance of specific fish species targeted for exploitation;
3. An assessment of coral fragmentation and grow-out methodologies against environmental impact;
4. Community consultations for inputs and comments;
5. Develop a management plan;
6. Establish a program to monitor activities over time;
7. Formulate procedures to track quantity/size of clams, corals and ornamental fish species exported;
8. Develop, as appropriate, policy guideline or legal framework to ensure compliance with international standards on codes of best practices for quarantine and international conventions; and
9. Recommend a training plan as necessary."

Before objectives 4-9 could be addressed, it was critical to conduct an assessment of the potential viability and sustainability of an aquarium trade fishery if it were to start in Pohnpei. Therefore, to best respond to Pohnpei's officially submitted request, the primary objectives of SPC's technical assistance were reformulated as follows:
In partnership with State and National Government agencies:

1. Conduct underwater commercial and transect surveys of marine aquarium fish resources around Pohnpei;
2. Determine the viability of establishing operations on island based on the survey's findings; and
3. Assess the ecological impact of coral fragmentation for mariculture purposes and review grow-out methods[2].

[2] Addressed in a separate report

ASSESSMENT OF MARINE AQUARIUM FISH RESOURCES

A review of the published and gray literature yielded a number of relevant reports (e.g., Allen 2006, Koshiba et al. 2012, Matsuoka et al. 1995, Yeeting and Itaia 2010), two of which in particular informed our surveys.

2005 Rapid ecological assessment

In 2005, the Conservation Society of Pohnpei (CSP), in conjunction with Pohnpei State partners, Department of Lands and Natural Resources (DNLR) and Department of Economic Affairs (DEA) undertook a Rapid Ecological Assessment (REA) of Pohnpei Island, and Ahnd and Pakin atolls in Pohnpei State. The decision to undertake the REA was based on a lack of adequate biological data to support the network of Marine Protected Areas (MPAs) in Pohnpei State. Surveys were therefore designed to assess marine biodiversity and status of marine resources for three key habitats (coral reefs and seagrasses). Survey results were then used to identify areas of biodiversity significance for protection and to provide advice on developing a resilient network of MPAs.

Fish surveys were undertaken by Dr. Allen at 41 sites to a maximum depth of 55m, between August and September 2005. A total of 470 species were recorded during the expedition, including 161 new distribution records and one new species.

While the list of species recorded during these surveys is useful to know what species were recorded at various locations, biodiversity surveys have limited application in helping determine sustainable commercial collection. This is primarily because biodiversity surveys:

- Focus on recording every single species encountered, rather than species of commercial interest, their size and colour phase; and
- Focus on presence/absence, making limited inferences with regards to abundance.

Possible commercial exploitation is not considered in biodiversity surveys. In instances where abundance is recorded next to a given species, it is to be interpreted from a biodiversity perspective and is not applicable in a commercial fishing context. In other words, during biodiversity surveys, if a fish species is observed at multiple sites, the surveyor is likely to qualify the fish as being common, even though overall density may be low.

2010 SPC marine aquarium fish resources assessment

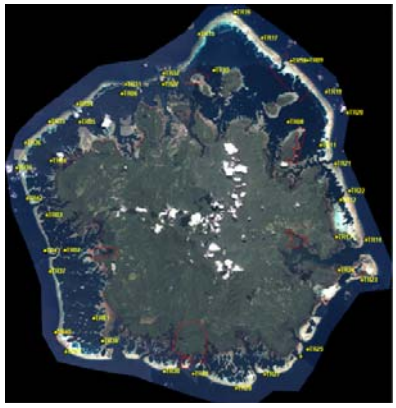

Figure 1 - Survey locations (in yellow) of the 2010 SPC-led aquarium fish assessment

Initial targeted aquarium surveys were conducted in 2010 by SPC staff in collaboration with Fisheries and Conservation Society of Pohnpei (CSP) staff, as well as staff from the Chuuk State Department of Marine Resources and Yap State Department of Resources and Development following a request submitted to SPC by the National Government as part of the Joint Country Strategy between FSM and SPC (Yeeting & Itaia 2010)[3]. The surveys were conducted as a baseline should anyone express interest in developing an aquarium industry at a later point in the future.

Fieldwork was conducted at a total of 42 sites distributed between lagoon and outer reef (windward and leeward) locations around Pohnpei Island (Fig. 1) using the distance sampling underwater visual

[3] Note data are unpublished and therefore densities as well as stock estimates for the different species were not available.

survey method (d-UVC) [4] along 50-m transects at an average depth of 10m. Surveyors recorded a total of 183 fish species from 27 main fish families of *possible* interest to the marine aquarium trade. Note that in addition to including a large number of low value species, as the aquarium trade is a dynamic sector, the majority of species considered of medium to high value at the time are no longer so.

2014 commercial surveys

The 2014 request for assistance submitted to SPC was in response to an official proposal by an established aquarium operator to assist Pohnpei in developing a high quality and sustainable aquarium fish and aquaculture export sector. To this end, findings from the surveys needed to inform the government whether, based on available fish resources, a sustainable and economically viable industry was possible.

For the purpose of this report, commercial surveys are defined as dive assessments conducted within the depth range from which marine aquarium species are typically safely collected (0-40m) and during which all species of potential interest for the marine aquarium trade are recorded and placed in one of three categories:

1. Species of targetable size and high abundance – these species typically constitute the main target species;
2. Species with some market value, but not commercially viable to export on their own (as they are in sufficient abundance to collect incidentally and export or they are not viable to export due to freight expense) – such species would not be targeted per se but would be collected if encountered during a dive;
3. Species with low or virtually no market value (thus not viable to export) – individuals observed on the reef are typically observed at too large a size or at too low abundances for example.

Marine aquarium trade commercial surveys are typically undertaken to determine the viability of starting a business. Assessments seek to inform and help determine which species are economically worth targeting and which are not.

Note that although the categories highlighted above form the integral part of commercial surveys irrespective of location, the actual species listed under these three categories will vary from one place to another. Factors affecting classification include, but are not limited to, freight rates, local abundances, observed sizes, habitat characteristics etc...

To determine species of likely commercial interest, a couple of days were allocated to scoping dives/snorkels at a number of contrasting locations on the outer reef and inside the lagoon. This allowed for the observation of species present, gauge general size of fish on the reef for given species, and estimate qualitative abundances for each species. Based on this assessment we then established a list of key species to be recorded at outer reef and lagoon sites (Table 1), created laminated illustrated species ID sheets (Appendix I) for these species, and assigned OFA staff to systematically and quantitatively record these along 50-m transects (see below) at between 20m and 10m depth, moving from deeper to shallower water throughout the day, according to dive safety protocols.

The list of key species consisted of a combination of species: (i) identified as critical to the development of a viable business, primarily because of their value; (ii) observed in fair numbers on the reef and that would provide some variety while also increasing total number of fish exported to make shipments

[4] The distance-sampling underwater visual census (d-UVC) method (Kulbicki and Sarramegna 1999, Kulbicki et al. 2000) consists of a fish census technique conducted along a transect line, where a diver records fish by species name, abundance, body length and distance to transect line. Fish density (number of fish per unit area) and biomass (weight of fish per unit area) estimates are calculated from the counts truncating data at 5m.

cost-effective cargo-wise; and (iii) commonly exported out of Kosrae.

Fieldwork was conducted around Pohnpei Island by a team of 4 to 5 people using SCUBA over a total of 13 days. Information recorded during these surveys included general habitat structure; reef profile; general qualitative abundance data for the majority of species of potential interest for the aquarium trade; and quantitative data for some key species identified during preliminary scoping dives.

Survey sites were chosen to span as many contrasting locations on the outer reef and in the lagoon as possible, thus covering as much of the circumference of the island as feasible given transport, time and weather conditions.

Table 1 - Species to be recorded along 50-m transects at outer reef and lagoon sites

Species to record on the outer reef	**Species to record in the lagoon**
Flame angelfish (*Centropyge loricula*)	Regal angelfish (*Pygoplites diacanthus*)
Coral beauty (*Centropyge bispinosus*)	Bicolor angel (*Centropyge bicolor*)
Regal angelfish (*Pygoplites diacanthus*)	Moorish idol (*Zanclus cornutus*)
Lemonpeel (*Centropyge flavissima*)	Blue tang (*Paracanthus hepatus*)
Dispar anthias (*Pseudanthias dispar*)	Tracey's damselfish (*Chrysiptera traceyi*)
Bartlett's anthias (*Pseudanthias bartlettorum*)	Rainford goby (*Koumansetta rainfordi*)
Whitecheek surgeon (*Acanthurus nigricans*)	Velvet wrasse (*Cirrhilabrus luteovittatus*)
Leopard wrasse (*Macropharyngodon meleagris*)	Richmond's wrasse (*Halichoeres richmondi*)
Banana wrasse (*Thalassoma lutescens*)	
Tracey's damselfish (*Chrysiptera traceyi*)	

Fixed width 50-m transect surveys

Surveyors placed a 50-m transect line parallel to the shoreline contour at a depth between 10m and 20m and recorded the total number of individuals for key fish species in a fixed width corridor of 2m either side of the transect line. This protocol was chosen over the d-UVC method for the following key reasons:

1. It is better suited to the highly cryptic and skittish nature of a number of species surveyed (e.g., *Centropyge loricula, Centropyge flavissima).* Indeed, surveys for marine aquarium fish must be conducted with a narrow field of vision because the vast majority of species, unlike most food fish, cannot be seen from a distance due to their small size, the fact that they stay close to the substrate, and that they frequently hide when disturbed from activities such as surveying; and
2. Reef habitat where flat pavement and or sand substrate is interspersed with high coral heads limiting the surveyor's ability to see or adequately identify small marine aquarium fish further than a few meters away.

Distance counts of Centropyge loricula

The flame angelfish, *Centropyge loricula* (Günther 1874), is one of the most popular reef fish in the marine aquarium trade. It is sourced exclusively from the Pacific region. Key to their appeal is their vibrant colouration and distinctive markings (Fig. 2). Flame angelfish are characterised by a bold orange to red body with up to seven broad black bars running vertically down each side. The edges of the anal and dorsal fins are black with a blue margin. This fish commands relatively high value on the market place with consistent demand, especially if exporters can supply high quality fish.

Figure 3 - *Centropyge loricula*, flame angelfish
(Photo: © C Wabnitz)

Given the importance of *Centropyge loricula* to the establishment of a viable fishery in Pohnpei, point-to-point swims were undertaken to locate and assess abundance of this species. This method consists in counting the number of fish of a given species within a fixed-width corridor between two markers. During this assessment, at depths between 10m and 20m, whenever suitable habitat was located, one of the authors would drop a marker attached to a buoy. Both authors then swam parallel to the reef contour line counting *C. loricula* individuals within a corridor extending 2m either side of their centre line, while making sure to not overlap in area surveyed. Once we moved out of suitable habitat or when coming to the end of the dive, a second marker attached to a fanion was dropped. At the surface, GPS points were taken of the fanion locations (Figure 2). This subsequently allowed for the distance over which *C. loricula* counts were conducted to be estimated. While estimating distance using GPS points suffers from errors in accuracy, this method was chosen as it is quick to implement and the surveyor doesn't scare fish through the deployment of cumbersome gear. Moreover, given that it is time efficient it allows surveys to be conducted safely in deeper water. While it is not sufficiently robust to allow for quota development or an exact stock estimate, it provides useful and valuable qualitative information about the relative abundance of a species. The information gathered also allows for inferences to be made as to whether a species would be vulnerable to over fishing or not.

Figure 2 - Float at the surface
(Photo: © C Wabnitz)

MAIN FINDINGS

All surveys were conducted between the 25th September and 13th October 2014 at a total of 32 sites indicated on Figure 4 (red dots). Surveyors spent a total of 13 days in the water covering outer reef and lagoon habitats (including one day spent at Ant (Anhd) atoll; not included in Figure 4 below).

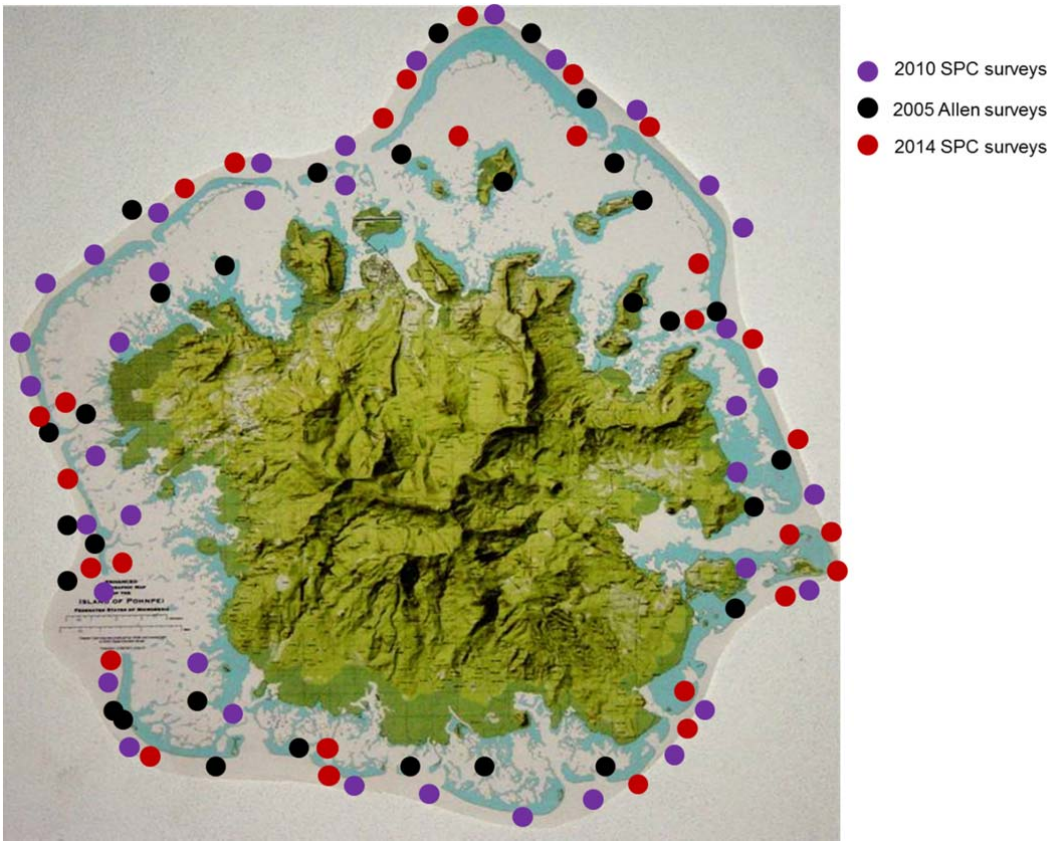

Figure 4 - Locations of surveys undertaken by SPC-led teams in 2010 and 2014 and sites at which fish biodiversity was assessed in 2005 by G. Allen (Allen 2006). This map does not include the locations covered on Ant atoll (three sites).

Commercial surveys

Following the initial scoping dives we established a list of species of possible commercial interest, to which we added: (i) species typically sought after in the trade and which would help establish the commercial viability of a business (e.g., *Paracanthurus hepatus*, *Neocirrhites armatus* – Figure 5 and Figure 6); as well as (ii) species currently exported out of Kosrae. Commercial visual surveys were conducted by a team of two surveyors and focused on identifying and recording qualitative abundance of a variety of species and quantitative data on key species of commercial interest.

Table 3 summarizes results of the commercial surveys undertaken over the 13 days of diving around Pohnpei Island. The rating in column two is a qualitative indicator of the observed approximate density at all sites combined that can be used to inform viability of an operator. For example, a low observed density will affect viability as follows:

Figure 5 - *Neocirrhites armatus,* red hawk (Photo: © C Wabnitz)

- Not all locations may have the species present;
- Fewer fish will be collected over a given time period with fishers spending time travelling between collection sites increasing cost of collection and lowering returns for the collector and the exporter; and
- Ecological sustainability of collection may be a concern and some form of monitoring should be put in place for these species.

The third column in Table 3 takes into consideration the total reef area available over which fish of a given species were observed and could be collected from. Thus, while density at a certain site may be low, negatively impacting total daily catch, there may be sufficient total stock available at the scale of the island to allow for the sustainable collection of a species. The fourth column provides an indication if the size of the fish commonly observed on the reef was considered suitable for aquariums (i.e., frequently fish can be found in good numbers on a reef, but they are too large for export).

Figure 6 - *Paracanthurus hepatus*, blue tang (Photo: © Tewy[6])

Based on the results obtained from the commercial surveys (Table 3) we drew up a list of species that fulfilled one or more of the following criteria: (i) available in Pohnpei in commercial quantities; and (ii) popular in the trade and of medium to high value, therefore critical to the commercial viability of an operator. Fish species with an export value of 8.00 USD[5] or greater were considered high value, whereas fish species of a value of 1.50 USD or less were considered low value (Table 2).

Table 2 – Species observed during commercial surveys, ranked according to value on the market and commercial abundance around Pohnpei.

Common name	Scientific name	Comments
Tracey's damsel	*Chrysiptera traceyi*	Commercial quantity
Leopard wrasse	*Macropharyngodon meleagris*	Commercial quantity - mostly seen on winward side
Rainford's goby	*Koumensetta rainfordi*	Commercial quantity
Dispar anthias	*Pseudanthias dispar*	Limited commercial quantity
Whitecheek surgeon	*Acanthurus nigricans*	Commercial quantity - mostly seen on windward side
Velvet wrasse	*Cirrhilabrus luteovittatus*	Commercial quantity (Common)
Richmond's wrasse	*Halichoeres richmondi*	Commercial quantity
Moorish idol	*Zanclus cornutus*	Limited commercial quantity
Banana wrasse	*Thalassoma lutescens*	Limited sommercial quantity (Nearly all female)
Lemonpeel	*Centropyge flavissima*	No commercial quantity
Coral beauty	*Centropyge bispinosus*	No commercial quantity
Bartlett's anthias	*Pseudanthias bartlettorum*	No commercial quantity (Infrequently seen)
Bicolor angel	*Centropyge bicolor*	No sommercial quantity
Flame angel	*Centropyge loricula*	No/very limited sommercial quantity - mostly seen on windward side
Regal angel	*Pygoplites diacanthus*	Commercial quantity
Blue tang	*Paracanthurus hepatus*	No commercial quantity

low value
medium value
high value

Only two species were considered high value, *Centropyge loricula* and *Pygoplites diacanthus*. *Centropyge loricula* was not found in commercial quantities on reefs around Pohnpei or Ant atoll (Table 3 andTable 2). This finding was corroborated by the targeted surveys for this species, with numbers per dive typically averaging less than 5. Reasonable to high densities of flame angels were encountered at only three locations out of a total of 22 dives at outer reef sites.

For the other species, *Pygoplites diacanthus*, while available in commercial quantities, the fish observed often did not satisfy the appropriate size for the marine aquarium market. Moreover, it is a species that is available throughout the Pacific region and is considered to be relatively difficult to maintain in captivity and therefore is targeted at experienced aquarists. Consequently it has a low weekly demand and cannot be considered a key fish to base a business on.

[5] As based on a rapid market assessment of the current value of these species on September 27-28, 2014.

[6] https://creativecommons.org/licenses/by-sa/3.0/deed.en

Table 3 - Family / species surveyed, abundance rating (1-5 with 1 being low and 5 high) and comments pertaining to commercial availability and size observed on reef

Family/ Species surveyed	Abundance Rating (1-5)	Commercial quantity rating	Sizes/Comment
Acanthuridae			
Acanthurus lineatus	1	Limited commercial quantity	Limited aquarium sized fish seen
Acanthurus nigricans	2	Commercial quantity	Mix of sizes but good sizes seen
Acanthurus pyroferus	1	Limited commercial quantity	Good sizes seen – *C. vrolikii* mimic
Ctenochaetus striatus	2	Commercial quantity	Mix of sizes but good sizes seen
Paracanthurus hepatus	None recorded	NA	NA
Zebrassoma scopas	2	Commercial quantity	Mix of sizes but good sizes seen
Apogon			
Apogon luteus	Recorded but not evaluated	Undetermined	Good sizes seen- Habitat specific
Sphaeramia nematoptera	Recorded but not evaluated	Undetermined	Good sizes seen - Habitat specific
Balistidae			
Melichthys vidua	0	Limited commercial quantity	Mostly large; aquarium sized fish rare
Odonus Niger	1	Limited commercial quantity	Mostly large, but some good sized fish seen
Blennidae			
Cirripectes variolosus	0	NA	NA
Ecsenius opsifrontalis	0	NA	NA
Cirripectes stigmaticus	0	NA	NA
Chaetodontidae			
Chaetodon punctatofasciatus	1	Limited commercial quantity	Mix of sizes but good sizes seen
Cirrhitidae			
Cirrhitichthys oxycephalus	None recorded	NA	NA
Neocirrhites armatus	None recorded	NA	NA
Gobidae			
Koumansetta rainfordi	3	Commercial quantity	Good aquarium sized fish seen
Nemateleotris magnifica	2	Commercial quantity	Good aquarium sized fish seen
Pictochromis sp.	None recorded	No species seen of this family	NA
Labridae			
Cirrhilabrus katherinae	1	Limited commercial quantity	Good aquarium sized fish seen
Cirrhilabrus luteovittatus	3	Commercial quantity	Good aquarium sized fish seen
Halichoeres melanurus	2	Commercial quantity	Good aquarium sized fish seen
Halichoeres melasmopomus	1	Limited commercial quantity	Good aquarium sized fish seen

Family/ Species surveyed	Abundance Rating (1-5)	Commercial quantity?	Sizes/Comment
Halichoeres richmondi	2	Limited commercial quantity	Good aquarium sized fish seen
Labroides pectoralis	<1	No commercial quantity	NA
Macropharyngodon meleagris	2	Commercial quantity	Good aquarium sized fish seen
Pseudocheilinus hexataenia	2	Commercial quantity	Good aquarium sized fish seen
Pseudocheilinus octataenia	0	NA	NA
Thalassoma lutescens	1	Limited commercial quantity	Males not seen/Size OK for females
Pomacanthidae			
Centropyge bicolor	1	Limited commercial quantity	Mix of sizes with good sizes seen
Centropyge bispinosus	1	Limited commercial quantity	Mix of sizes with good sizes seen
Centropyge flavissima	1	Limited commercial quantity	Mix of sizes with good sizes seen
Centropyge heraldi	1	Limited commercial quantity	Good aquarium sizes seen
Centropyge loriculus	1	Limited commercial quantity	Good aquarium sizes seen
Centropyge multicolor	1	Limited commercial quantity	Good aquarium sizes seen
Centropyge vrolikii	2	Commercial quantity	Mix of sizes with good sizes seen
Pygoplites diacanthus	3	Commercial quantity	Majority too large but some aquarium sized fish seen
Pomacentridae			
Amphiprion chrysopterus	1	Limited commercial quantity	Good aquarium sizes seen
Amphiprion clarkii	<1	No Commercial quantity	NA
Amphiprion melanopus	1	Limited commercial quantity	Mix of sizes with good sizes seen
Amphiprion perideraion	<1	No Commercial quantity	NA
Chromis acares	2	Commercial quantity	Good aquarium sizes seen
Chrysiptera traceyi	2	Commercial quantity	Good aquarium sizes seen
Chromis vanderbuilti	0	NA	NA
Chromis viridis	4	Commercial quantity	Good aquarium sizes seen
Serranidae			
Pseudanthias bartlettorum	<1	No Commercial quantity	NA
Pseudanthias dispar	1	Limited commercial quantity	Good aquarium sizes seen
Pseudanthias pascalus	2	Commercial quantity	Good aquarium sizes seen
Syngnathidae			
Corythoichthys sp.	2	Commercial quantity	Good aquarium sizes seen
Zanclidae			
Zanclus cornutus	1	Limited commercial quantity	Good aquarium sizes seen

For two key species, the leopard wrasse (*M. meleagris*) and the whitecheek surgeonfish (*A. nigricans*), while these were available on the reef in "commercial quantity" they were mostly seen on the windward side of the island, which would limit fishers' access to this species, if an operator was to establish himself/herself on island.

Fixed width 50m transect surveys

The fixed width transects were conducted by a team of two surveyors over the course of 9 days between the 30th September and 9th October and focused on recording quantitative data for key fish species (see Appendix I) at outer reef and lagoon sites. Fish counts were performed for a total of 31 transects on the outer reef and 6 transects in the lagoon. Estimated densities are presented in Table 4.

Table 4 – Densities of key fish species estimated along 50m x 2m transects at 31 outer reef and 6 lagoon sites. For shaded areas see text for explanation.

Outer reef	**Density/m²**
C. traceyi	0.075
P. dispar	0.060
A. nigricans	0.041
M. meleagris	0.008
C. flavissima	0.006
Z. cornutus	0.005
P. diacanthus	0.005
C. loricula	0.004
C. bispinosus	0.004
T. lutescens	0.000
P. bartlettorum	0.000

Lagoon	**Density/m²**
C. traceyi	0.067
C. luteovittatus	0.065
K. rainfordi	0.060
C. bicolor	0.018
P. diacanthus	0.010
Z. cornutus	0.008
H. richmondi	0.000
P. hepatus	0.000

Similarly to the commercial surveys, results showed that on the outer reef, *C. traceyi* was by far the most common species, followed by *A. nigricans*; while in the lagoon *C. traceyi, C. luteovittatus* and *K. rainfordi* were the most common.

While results also showed *P. dispar* to be fairly common, this finding is misleading as this species displays schooling behavior with surveyors counting as many as 116 individuals on one transect at one location. Out of a total of 31 transects at outer reef locations *P. dispar* was found on 5 transects (corresponding however to only 2 geographical locations).

Densities of *C. loricula* included in the table are based on data from a total of 28 transects only – as three transects were conducted at two sites that we targeted specifically because we had previously identified as having high flame angel density counts. These locations are therefore not representative of any other location surveyed. Results show densities of flame angel to be much lower than in Kosrae (0.011 / m² (Yeeting & Palik 2008) and 0.01 / m² (Wabnitz & Nahacky 2014)) or Nauru (0.062 / m² (Yeeting & Thoma 2008)).

While *C. bispinosus* was not considered common based on commercial surveys, it is to note that we typically spotted them in waters > 25m (10m deeper than at most other sites in the region) and therefore it is not surprising that the team did not see many while conducting transect surveys, which were conducted on 10m to 20m of water.

Habitat

Habitat information was recorded at all surveyed sites (Table 5). Outer reef sites were found to show large variation in the type of reef structure present. Typically sites were characterized by (a combination of) the following overarching classifications:

- Sheer drop-off;
- Steep slope;
- Gentle slope;
- Boulders;
- Pavement with and without small coral colonies;
- Rubble zones;
- High branching and tabular coral cover, both alive and dead;
- Varying degree of *Halimeda* sp. (algae) coverage;
- Sand sections; and
- A wide to narrow band of reef width (depending on slope) extending from the barrier reef to 40m depth.

Lagoon habitats also were found to show large variation but were generally shallower and characterised by greater coral coverage consisting of a greater diversity in both hard and soft coral species:

- Sheer drop-off;
- Steep slope;
- Gentle slope;
- Rubble zones;
- Sand sections;
- High branching and tabular coral cover both alive and dead; and
- Varying degree of *Halimeda* sp. (algae) coverage.

Table 5 – Habitat descriptions for every single survey conducted

Date	Survey type	Habitat	Outer Reef	Lagoon
26/9/14	SCUBA	Pavement to 8m changing to rocks and occasional coral head or colony to 15m followed by steep drop-off	*	
26/9/14	SCUBA	Mixed species corals interspersed with sand patches. *Porites* sp. and various staghorn *Acropora* sp. common		*
27/9/14	SCUBA	Pavement with small coral colonies to 6m followed by mixed coral and rock to fast slope beginning at 15m	*	
27/9/14	SCUBA	Staghorn *Acropora* sp. to 8m, small shelf with rock and interspersed live coral to 15m, followed by fast slope	*	
27/9/14	SCUBA	Rubble and sand bottom with rock outcroppings and strands of live coral to 8-14m then steep rock drop-off		*
29/9/14	SCUBA	Pavement to 10m with occasional cracks and small coral colonies then very flat slope with rock, rubble, and coral patches to 25m	*	
29/9/14	SCUBA	Pavement to 10 m with occasional cracks and small coral colonies then very flat slope with rock, rubble, and coral patches to 25m	*	
29/9/14	SNORKEL	Large patches of partially dead staghorn *Acropora* sp. with algae, sand, rubble, and patches of mixed coral species such as *Goniopora* sp., *Porites* sp., and *Montipor* sp.		*
30/9/14	SCUBA	Pavement to 10m then very flat slope with rock slab, cracks, rubble, and large *Porites* sp. coral heads	*	
30/9/14	SCUBA	Very flat slope with dense live Staghorn *Acropora* sp. strands until 10 m then mixed rubble and *Acropora* sp. strands to 15m	*	

30/9/14	SNORKEL	Fire coral dominant or some sections predominantly covered in *Halimeda* sp. with 2-3 m drop-off to sand, rubble, and coral rock outcroppings; slab in extreme shallow		*
01/10/14	SCUBA	Pavement to 8m with table top *Acropora* sp. followed by gentle slope with mixed rubble/consolidated rubble, rock and coral patches to 20m	*	
01/10/14	SCUBA	Pavement to 4m then rock rubble to 7m with staghorn *Acropora* sp. strands and extensive *Halimeda* sp. beds to 15m giving way to mixed rubble and live coral	*	
01/10/14	SNORKEL	Sections of soft corals in 1 m depth along with extensive zones of rubble, and massive *Porites* sp. heads		*
02/10/14	SCUBA	Pavement to 8m with small coral colonies, followed by gentle slope with consolidated rubble, rock and occasional coral to 25m giving way to fast slope with rock and rubble	*	
02/10/14	SCUBA	Pavement to 8m with small coral colonies, followed by gentle slope with consolidated rubble, rock and occasional coral to 25m giving way to fast slope with rock and rubble	*	
02/10/14	SCUBA	Rubble and sand bottom with rock outcroppings and strands of live coral down to 8-14m depth, then steep rock drop-off		*
04/10/14	SCUBA	Boulder pavement to 6m depth followed by short rock bench, rock outcroppings, infrequent small coral colonies to 20m followed by fast slope with rubble at bottom	*	
04/10/14	SCUBA	Boulder pavement to 6m, followed by short rock bench, rock outcroppings, infrequent small coral colonies to 15m then drop-off	*	
5/10/2014	SCUBA	Boulder pavement to 6m, followed by medium-width rock bench, rock outcroppings, infrequent small coral colonies to 15m then drop-off	*	
5/10/2014	SCUBA	Boulder pavement to 6m, followed by medium-width rock bench, rock outcroppings, infrequent small coral colonies to 15m then fast slope	*	
6/10/2014	SCUBA	Boulder pavement to 6m, followed by medium-width rock bench, rock outcroppings, infrequent small coral colonies to 15m then fast slope (flames observed in *Halimeda* sp. bed)	*	
6/10/2014	SCUBA	Boulder pavement to 6m, followed by medium-width rock bench, rock outcroppings, infrequent small coral colonies to 20m then fast slope	*	
6/10/2014	SNORKEL	*Porites* sp. heads, *Halimeda* sp. beds, *Millepora* sp. stands, rubble and a variety of coral patches with mixed species in 1m and less of water		*
7/10/2014	SCUBA	Gullies to 5m, followed by medium-width rock bench, rock outcroppings, dead branching corals with heavy coralline algae encrustation, patches of *Halimeda* sp., infrequent small coral colonies to 20m followed by fast slope	*	
7/10/2014	SCUBA	Gullies to 5m, followed by medium-width rock bench, rock outcroppings, dead branching corals with heavy coralline algae encrustation, patches of *Halimeda* sp., infrequent small coral colonies to 20m followed by fast slope	*	
7/10/2014	SNORKEL	*Porites* sp. heads, sand areas, rubble and a variety of coral patches with mixed species in 3m and less of water	*	
8/10/2014	SCUBA	Short-width reef with rock, rock outcroppings, dead branching corals, and small coral colonies to 12m followed by steep drop-off	*	
8/10/2014	SCUBA	Drop-off from barrier reef to 5m, followed by medium-width rock bench with large boulders, rock outcroppings, small coral colonies with large patches of sand to 12m giving way to drop-off	*	
8/10/2014	SNORKEL	Variety of *Porites* sp., *Acropora* sp., sand, dead and live branching corals, with drop offs 3-7m on edge		*
9/10/2014	SCUBA	Flat pavement with small coral colonies to 6m, live and dead coral to 15m, then rubble interspersed with coral and sand patches, wide reef with slowly descending slope	*	
9/10/2014	SNORKEL	Sand with *Porites* sp. colonies with variety of coral patches with large Millepora sp. and *Porites cyclindrica* at the edges		*

CONCLUSIONS

Thirteen days of diving gave us the opportunity to cover a range of sites at as many locations as possible given time, transport and weather constraints. While a few species were found in commercial numbers (see Table 3 and Table 2), their market and export values are highly unlikely to allow for the development of a viable business. Most importantly, key species such as flame angelfish (*C. loricula*) and bartlett's anthias (*P. bartlettorum*) were found only at specific locations and in very low densities. Furthermore, habitat in which *C. loricula* was typically found generally was not conducive to collection. Four scuba dives by two experienced and skilled collectors were undertaken to collect specimens of *C. loricula* for scientific study of their age and genetics. They collected a total of 13 fish on 8 SCUBA tanks (or 1.63 Flame per bottle). This rate of collection would not be considered viable as it would not even cover expenses for a boat, fuel, dive gear, and compressed air.

We note additional observations that further reduce the possible viability of a marine aquarium enterprise in Pohnpei. Firstly, most fish in terms of diversity and abundance were observed on the windward side of the island, complicating logistics in terms of access and therefore increasing the number of days divers would not be able to collect. Even on the less exposed side, outer reef areas, where the majority of the medium to high value fish can be found, are often subjected to strong current and/or heavy surf increasing difficulty of collection. Secondly, many of the higher value fish are found at greater depths in Pohnpei than on either Kosrae or the Marshall Islands, where they are also being exported from. This not only restricts the amount of time divers can remain at depth and thus collect fish, it makes collection potentially unsafe and increases cost of collection, diminishing returns per fish. Individual fish are also likely to be of lower quality due to superior decompression needs, having been caught at greater depths. Thirdly, a large portion of the habitat in which fish were spotted consists of dense coral or deep coral rubble often carpeted with *Halimeda* sp. in which the fish can stay deep and hide, and escape from set nets with ease. It also increases the difficulty in catching fish without damaging the habitat. Fourthly, we did not record a single individual of other key high-value/demand species such as blue tang (*P. hepatus*) and red hawk (*N. armatus*). Allen in 2005 only recorded one blue tang and not a single red hawk in 52 hours of diving at 41 sites to a maximum depth of 55m (Allen 2006). Lastly, while the lagoon offers a variety of fish at commercial densities, they are all considered low value.

In addition to the above ecological limitations, the following operational constraints were identified:

- all packing materials (e.g., plastic bags, boxes and insulation material) would have to be sourced externally as these are not currently manufactured locally, increasing costs;
- limited cargo space is available leaving Pohnpei; and
- higher than average freight rates.

In conclusion, all available information and survey findings do not support the establishment of a sustainable and/or viable industry to be developed on Pohnpei. We therefore do not recommend that Pohnpei and/or an operator invest time, finances or effort in developing such a fishery.

Flame angelfish (C. loricula)

Observations and data collected during this assessment lead us to conclude that *C. loricula* would be a "species of concern" if Pohnpei were to consider starting an aquarium industry despite recommendations laid out in this report (see above). Indeed, this species is in high demand and orders could easily exceed what could sustainably be collected, quickly leading to over collection of this species. Moreover, as this species was typically found in habitat from which it is extremely difficult to collect, mostly thick *Halimeda* sp. beds with fish hiding deep within the algae/reef lattice, collection could easily lead to unacceptable habitat damage. While we found individuals of this species at various

locations around the island, densities were low to extremely low at all sites; with a couple of exceptions. Low densities were recorded regardless of the method used. Of further concern is that in each instance, the total area over which fish were spotted around Pohnpei island was small (incl. narrow depth range). In Nauru, where flame angelfish densities were high (Wabnitz and Nahacky 2013), the depth range over which we observed fish ranged between 4m and 40m; in Pohnpei fish were spotted typically below 8m to a maximum depth of 25m.

Given observations on the ground, this species would be vulnerable to over-collection if it was targeted and its population would need to be monitored closely and carefully.

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Appendix I

Fish species to be recorded along 50-m transects on the outer reef

Outer Reef focal species

Flame angelfish (*Centropyge loricula*)

Lemonpeel (*Centropyge flavissimus*)

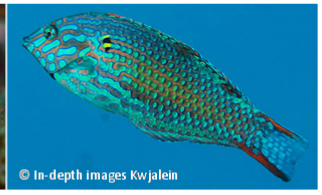
Coral beauty (*Centropyge bispinosus*)

Dispar anthias (*Pseudanthias dispar*)

Regal angelfish (*Pygoplites diacanthus*)

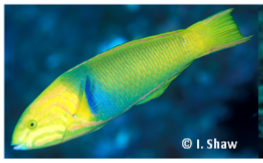
Bartlett's anthias (*Pseudanthias bartlettorum*)

Whitecheek surgeon (*Acanthurus nigricans*)



Leopard wrasse *(Macropharyngodon meleagris)*

Traceyi damselfish (*Chrysiptera traceyi*)



Banana wrasse (*Thalassoma lutescens*)

Fish species to be recorded along 50-m transects in the lagoon

Lagoon focal species

Regal angelfish (*Pygoplites diacanthus*)

Traceyi damselfish (*Chrysiptera traceyi*)

Bicolor angelfish (*Centropyge bicolor*)

Old glory (*Koumensetta rainfordi*)

Moorish idol (*Zanclus cornutus*)

Velvet wrasse (*Cirrhilabrus liteovittatus*)

Blue tang (*Paracanthus hepatus*)

Richmond's wrasse (*Halichoeres richmondi*)