Yellow coral goby (*Gobiodon okinawae*) trade in Banggai Laut District, Indonesia

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Abstract. We present one year of buying and selling data of the yellow coral goby (*Gobiodon okinawae*) in Banggai Laut District, Banggai Archipelago, Central Sulawesi, Indonesia. This data is the first to demonstrate that this species is being captured and exported from the region to be sold in the global saltwater aquarium trade. We present frequency, volume, mortality, as well as profit margin for collecting and selling this species. We also describe first-hand observation of how these fish are typically caught in the region. Additionally, we argue that harvesting the yellow coral goby presents a potentially sustainable alternative or additional source of income for fishers, especially compared to targeting another popular aquarium species in the region, the royal blue tang (*Paracanthurus hepatus*). For the former species, fishers use a large scoop net known as a "serok", while for the latter, fishers often use illegal chemical anesthetics. While more still needs to be understood about the trade in yellow coral goby in Banggai Laut District, this data provides initial insight into the trade and its livelihood and sustainability potential.

Key Words: aquarium trade, reef fish, sustainable fisheries, Sulawesi, Gobiidae.

Introduction. The global marine aquarium trade (MAT) involves nearly 2,300 different species sourced from over 40 different countries, with Indonesia being the second largest exporter in the world (Rhyne et al 2017). Thousands of fishers across the country are involved in the trade as part of their fishing portfolio, but still relatively little is understood about how the trade contributes to fisher livelihoods (Ferse et al 2012). The trade has also been controversial due to instances of overcollection resulting in decreased local wild populations, for example, in Indonesia (Madduppa et al 2014), the Philippines (Shuman et al 2005), Australia (Whitehead et al 1986), and Hawaii (Tissot & Hallacher 2003) as well as the use of harmful neurotoxins to aid in collecting certain species of aquarium fish (Rubec 1986; Halim 2002; Murray et al 2020). Here we look at a case in Indonesia where there is an emerging fishery of a species that may potentially avoid some of these concerns while adding to local fishers' ability to diversify their livelihoods, which can be critical to the well-being of remote coastal communities (Ferse et al 2012).

The Banggai Archipelago is one of the groups of small islands in the seas around Sulawesi, one of the five large islands in Indonesia. At the heart of the Wallacea and Coral Triangle biodiversity hotspots, administratively the Archipelago is divided into two districts within Central Sulawesi Province (Ambo-Rappe & Moore 2018). Banggai Kepulauan District comprises the northern part of the archipelago, including the largest island, Pulau Peleng, while Banggai Laut District to the south is comprised of the four next largest islands (Banggai, Labobo, Bangkurung and Bokan) with hundreds of smaller inhabited and uninhabited islands.

The diverse fish fauna of the Banggai Archipelago (Allen & McKenna 2001) includes the globally popular Banggai cardinalfish, *Pterapogon kauderni* (Koumans, 1933), with an endemic (native) distribution of less than 34 km^2 spread over less than 5,000 km^2 (Vagelli 2011). The majority of the *P. kauderni* distribution is in Banggai Laut District and also within a recently established Central Sulawesi provincial marine protected area (Ndobe et al 2019), hereafter referred to as the Banggai MPA. This MPA, which is not yet operational, comprises waters in Banggai and Banggai Kepulauan Districts as well as the waters around all but the two easternmost inhabited islands in Banggai Laut District (Sonit and Tempaus).

The Banggai MPA was established due to the automatic revocation of previously established district level MPAs when the law UU 23/2014 on Regional Governance transferred governance of coastal waters from 0-4 NM offshore from district or city to provincial governments (Moore & Ndobe 2013; Ndobe et al 2018, 2019; Wiadnyana et al 2020). UU 23/2014 gives provinces extensive rights and responsibilities for waters from the high tide line to 12 NM, with boundaries between neighboring provinces following the United Nations Convention on the Law of the Sea (UNCLOS), while archipelagic districts such as Banggai Laut lost control over most of their previous territory and resources (Ambo-Rappe & Moore 2018). During the interim period between the almost total cessation of district-level government rights and responsibilities with respect to marine resource management and the (still embryonic) establishment of provincial level governance structure, a *de facto* unregulated open access situation has prevailed in much of the Banggai Archipelago. This situation has resulted in accelerated exploitation and marine and coastal resources, including fish and invertebrates as well as ecosystem degradation (Moore et al 2019; Ndobe et al 2019).

One of the livelihood strategies in the Banggai Archipelago is the collection of fishes destined for the marine aquarium trade (MAT). A relatively small number of fishers from several villages have been known to engage in the aquarium trade as part of their livelihood strategy since the 1990's (EC-PREP 2005; Lunn & Moreau 2004). Initially, the endemic species *P. kauderni* or Banggai cardinalfish (traded as BCF) was the only species caught and traded by local fishermen, with other species (e.g. the high-value blue tang *Paracanthurus hepatus*) being collected by roving fishermen (EC-PREP 2005). Mainly from Bali and East Java or North Sulawesi, these roving fishers also purchased BCF from (and sometimes employed) local fishermen. Less than five years after the BCF trade began, *P. kauderni* was already considered at risk of extinction in the wild (Allen 2000). Twice proposed for CITES Appendix II listing, *P. kauderni* is now a priority conservation species of the Indonesian Ministry of Marine Affairs and Fisheries (MMAF) and Indonesia must report on progress at the CITES Animal Commission meetings (Ndobe et al 2018). BCF conservation was a major driver of MPA creation, initially at district and later at provincial level (Wiadnyana et al 2020), and the BCF is one of the main conservation targets of the Banggai MPA.

Banggai cardinalfish were not being captured and sold while the lead author was in the field, despite being noted as the primary species of interest in the early 2000's (EC-PREP 2005). Banggai cardinalfish are sedentary, and remain clustered around their preferred microhabitats throughout their lifecycle (Kolm et al 2005); in particular diadematid sea urchins and sea anemones but also hard corals and others (Moore et al 2019). One reason for the early involvement of locals in the BCF fishery is that *P. kauderni* are typically easy to catch using a hand net, on foot and/or free-diving in readily accessible sheltered shallow coastal waters 1-5 m in depth. This is in contrast to most other ornamental species, in particular the blue tang (known and traded locally as "letter six"), which are shier and difficult to catch; these higher value fishes were (EC-PREP 2005) and still are typically captured with a neurotoxin such as potassium cyanide (locally known as "potas"). The use of these toxic substances poses sustainability concerns (Dee et al 2014) due to environmental damage as well as elevated levels of mortality among the fish captured (EC-PREP 2005). Once captured, ornamental fish are generally sold to local middlemen, who ship them on to Luwuk, typically via a large ferry, from where they are mostly flown to Bali or Jakarta (Ndobe et al 2018). Undeclared (and therefore illegal) trade routes by sea to Kendari were still known to operate in 2018, although the other trade routes by sea (mainly to Manado and Bali) in the earlier decades of the trade seem to have died out over the past decade (Ndobe et al 2019).

While the BCF and letter six are known to be sourced from the region for over two decades, a new target species appears to have emerged over the past 5-10 years. Some fishers and traders in the region are now targeting the lower-value yellow coral goby, *Gobiodon okinawae* (Sawada et al 1972). This is notable, as this species is the 24th most imported to the U.S. by volume (Rhyne et al 2017; Dee et al 2019) and the 20th most imported into the European Union (Biondo 2017). While commercial scale captive breeding has been reported for many species, including *G. okinawae* (Borneman & Lowrie 2001), the majority of marine ornamental fishes are still sourced from the wild, often unsustainably due to the volumes and/or methods used (Olivotto et al 2011; Domínguez & Botella 2014). However, it is remarkable that *G. okinawae* was also recently found to be among the least vulnerable species of popular aquarium fish (Dee et al 2019). This low vulnerability rating was based on its relatively high productivity (an approximation of the ability to rebound from depletions based on 10 life history traits) and low susceptibility to overfishing (based on 12 catchability, management, and fishing practice attributes). It should be noted however that, despite the high overall productivity rating, fecundity was in the lowest category, while several of the overfishing susceptibility attributes used in the analysis by Dee et al (2019) are location-specific, and therefore might not apply to all ornamental fisheries targeting this species.

Originally described from the Yaeyama Islands, the southernmost islands of Okinawa Prefecture in Japan (Sawada et al 1972), *G. okinawae* appears to have a wide Western Pacific distribution, stretching southwards to Australia and from Indonesia eastwards to Micronesia (Munday 2000; Froese & Pauly 2020). Across this range, their preferred habitat appears to be sheltered waters such as lagoons (Munday 2000). Like many other gobies, including at least seven other members of the genus *Gobiodon* (Cole 2011), *G. okinawae* is a bi-directional hermaphroditic species with individuals able to switch between male and female function (Cole & Hoese 2001). The gonad of both juveniles and female-active (ova-producing) fish is ovariform, while male-active (sperm-producing) individuals have an ovotestis.

Obligate coral dwellers (Cole 2011), members of the genus *Gobiodon*, including *G. okinawae*, are reported as corallivores (Cole et al 2008; Brooker et al 2010). This may be related to their reproductive habits, as they have been observed removing coral tissue to create a small bare patch on which to lay their eggs (Randall & Delbeek 2009). One of the most cosmopolitan members of the genus, *G. okinawae* is known to associate with at least 11 species of corals (Hing et al 2019) and, like several other gobies, it has a relatively long potential life span of at least 13 years (Randall & Delbeek 2009). It is thought that this species may have few natural predators because, like most *Gobiodon*, *G. okinawae* produces a skin toxin (Hashimoto et al 1974).

Typically, gobies of the genus *Gobiodon* live in monogamous pairs, and tend to exhibit extremely high site fidelity, only moving when they lose their partner or the coral on which they live is broken or dies (Nakashima et al 1996). Given this way of life, bi-directional hermaphroditism has the obvious advantage that any two individuals can potentially form a reproductively active pair. *G. okinawae* is unusual among its congeners in that it commonly forms larger groups, schooling in the water column further from the coral colonies with which it is associated than most other *Gobiodon* species, possibly to maximize opportunities for planktivory (Cole & Hoese 2001). However *G. okinawae* can also be found living in pairs, and had a social plasticity index close to 0.5 (50% living in groups and 50% in pairs) in a study at Lizard Island, Australia (Hing et al 2018, 2019).

This paper represents the first attempt to characterize and quantify the trade in the yellow coral goby *Gobiodon okinawae* from the Banggai Laut District, as a baseline for understanding collecting practices, volume, fisher participation, frequency, mortality, and contribution to fisher and trader income. In doing so, we consider how this species may help fishers diversify their fishing portfolio, especially during periods of inclement weather and religious holidays that prohibit the use of diving equipment.

Material and Method

Description of the study sites. This study was conducted in the Banggai Archipelago, Banggai Laut District, Central Sulawesi Province, Indonesia from October 2018 to September 2019. The primary study site for the yellow goby data set was Toropot Village in the Bokan Kepulauan Sub-District, although one of the traders was from Bone Baru Village in Banggai Utara Sub-District (Figure 1). Observational data were collected during fishing trips to the coral-mangrove areas immediately adjacent to Toropot as well as around the island of Kokudang.

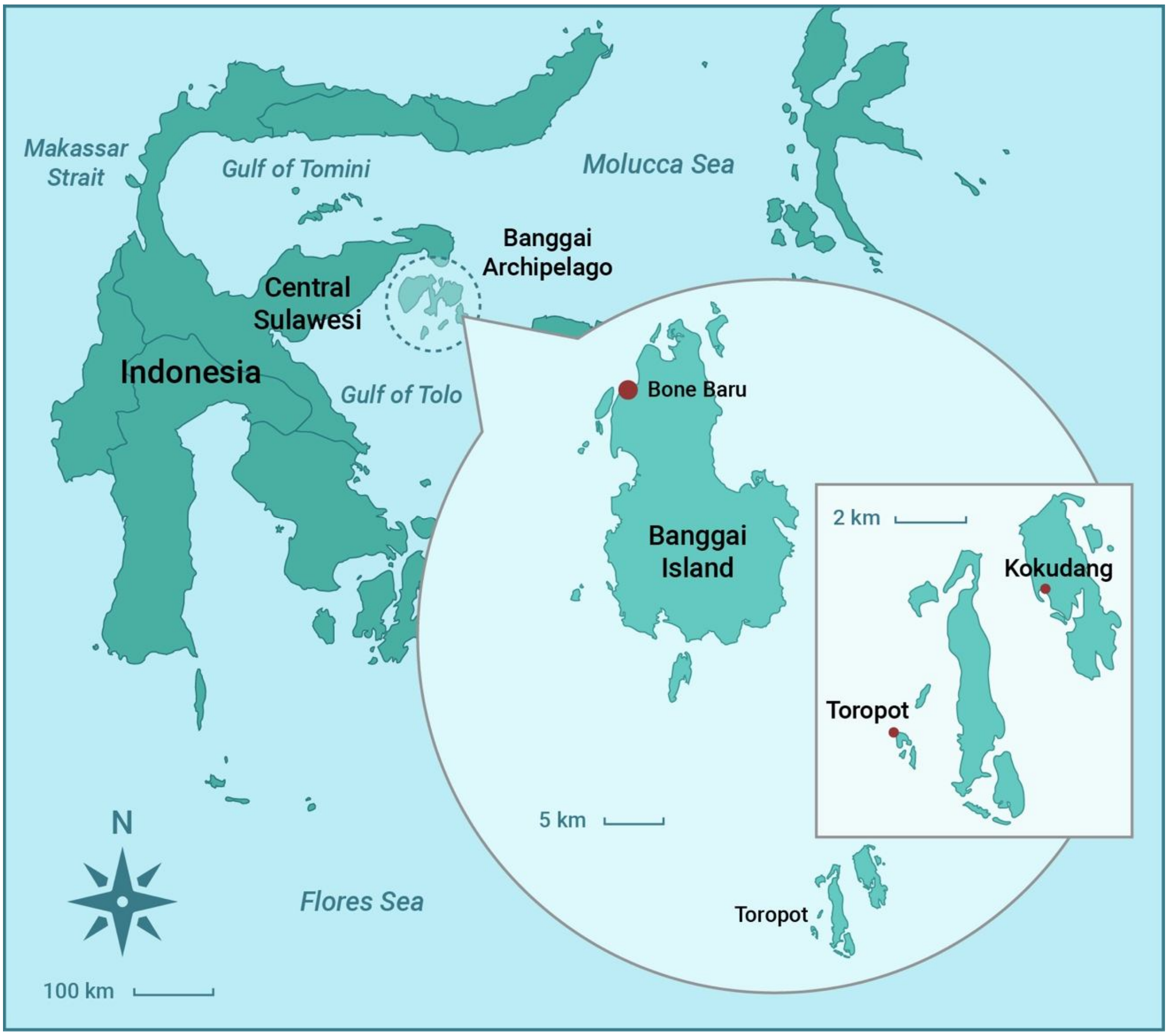

Figure 1. Map of the Banggai Archipelago, Indonesia showing the study site. Map copyright Ben Swanson.

Data sources. For this paper, we draw from two sources of data. First, from one year of buying and selling *G. okinawae* records, from October 2018 through September 2019, from two traders based in the Banggai Laut District (Trader A & Trader B for purposes of this paper). Second, from a year of participant observation and informal interviews conducted by the lead author, while she lived for several months at a time over the course of the year with a fishing family in Toropot village, the primary fish trading hub in the region. She accompanied fishermen on their fishing trips, including two trips that involved the fisher targeting the species of interest, *G. okinawae*. Here, we focus primarily on the former data and use the latter observational data to give more contextual detail to inform methods fishers used to catch the target species as well as how trading the *G. okinawae* fits into the larger fishery in the region.

We primarily focus on the data from Trader A, as Trader B only recorded two instances of buying and selling *G. okinawae*, with his primary focus being on the blue tang *P. hepatus*. While Trader A lived in Toropot adjacent to fishing grounds where *G. okinawae* were collected, Trader B lived on the nearby island of Banggai, about 4-5 hours away by local ferry in good weather. Therefore, it was more difficult for Trader B to coordinate the buying and selling of *G. okinawae*, since the species needs to be packaged and shipped quickly after being caught (typically 24-48 hours), unlike the primary target species, the *P. hepatus*, which can be stored in net pens under the fishers' houses for weeks or months. Therefore, we discuss Trader B's data where informative, but focus on the more comprehensive data of Trader A. Being a resident in the source village, Trader A bought and sold *G. okinawae* throughout the time span of the year of data collection (10/18-9/19). To the lead author's knowledge, these were the two primary, and likely only, aquarium fish traders who bought and sold this species from the Banggai Laut District at any sizeable volume.

Traders A & B recorded their data as they bought and sold fish in a physical notebook using the rubric shown in Table 1. The lead author collected this data on a monthly basis, taking photos of the data pages in order to leave the data book intact, and compensated the traders 150,000 IDR/$10.50 USD (using .00007 exchange rate) per month. To ensure this amount was appropriate and fair, it was the same rate that an Indonesian non-governmental organization, The Indonesian Nature Foundation (LINI), was concurrently compensating fish traders on the main island of Banggai for recording their catch data. For the year that Traders A & B were recording the data, the lead author was living in both the source village and the main island of Banggai and could check that the traders were recording the data regularly, rather than from memory after a long-time lapse, which would carry a higher risk of introducing error.

Table 1

Data entry items for aquarium fish traders

No.	*English*	*Indonesian*
1	Date	Tanggal
2	Name of fisher	Nama nelayan
3	Tool used	Alat tangkap
4	Location	Lokasi
5	Local fish name	Jenis ikan
6	Total bought individuals	Jumlah ikan yang dibeli
7	Price per fish (IDR)	Harga per ikan (Rp.)
8	Amount died	Jumlah ikan mati
9	Total sold individuals	Jumlah ikan yang dijual
10	Price sold/fish (IDR)	Harga jual/ikan (Rp.)

Data analysis. All data were analyzed descriptively. In order to characterize this previously undocumented fishery in the region, we present volume, fisher participation, frequency, mortality, and total income for one year of trade of *G. okinawae* in the Banggai Laut District. We also describe first-hand observations of how these fish are typically caught in the area.

Results

Collecting practices. Based on two participant observation trips with a fisherman catching *G. okinawae* and observing other fishers catching the species in the same vicinity, as well as multiple interviews with Trader A and B, there is a general strategy to catching the fish. Fishers use what is called a "serok" or a fine mesh net that is attached to a circular opening with a handle (Figure 2A). They do not use cyanide or any other chemical neurotoxin that is often used to catch the primary aquarium species in the region, *P. hepatus*, as this species is too small, and the mortality rate would be too high. This species is also easier to catch than *P. hepatus*, as individuals tend to cling to the branching corals where they live in large groups. This means fishers can scoop them off the corals using the *serok*. Fishers seek a relatively shallow area, where they are still able to stand and pull their boats along with them as they catch the fish and walk along the reef (Figure 2B).

Another strategy, one that could be considerably more destructive, is to dislodge a whole coral colony and shake it into the net in order to capture as many of the individuals as possible and minimize escapees (Figure 2C). Presumably this ultimately results in some (possibly significant) coral death. This is in addition to any damage caused by the fishers walking through the reef area; if they can afford them, fishers adorn their feet in rubber boots to avoid cuts and abrasions from the reef, possibly making them less careful when walking across the reef and thereby increasing damage. The fishers store the fish in any container they can find, with some using a "gabus" or white Styrofoam container, which helps to deflect the sun (Figure 2A, B). They change the seawater periodically to maintain oxygen levels and keep the water temperature cool, and they bring the fish directly to the trader at the end of the collecting session to sell their catch the same day.

Figure 2. Capture of *G. okinawae*: A. A fisher takes *G. okinawae* out of the *serok* net and transfers it to the *gabus,* or styrofoam container, filled with seawater to store until he brings his catch to the trader; B. A fisher searches for *G. okinawae* as he pulls his boat behind him and walks along a shallow coral reef; C. A fisher shakes a coral head into his *serok* to dislodge *G. okinawae* from their coral perch and secure them in the net. Photographs by Shannon Switzer Swanson.

Trade volume. The total volume of *G. okinawae* recorded during one year was 59,270 individuals for both Trader A and B. However, Trader A represented 96.17% of these sales, recording 57,000 individuals bought and sold, as opposed to Trader B, recording only 2,270 individuals in total over the same time period. This total volume averages to 4,939 individuals per month. The highest volume of individuals bought and sold was in October 2018, representing 17.45% of all individuals caught for the year, followed by June 2019 (Figure 3). Trader B only bought and sold *G. okinawae* in January and April. No *G. okinawae* were bought or sold in December, which could be because Trader A was staying with family at a nearby island and purchasing lobster and sea cucumber, which he also traded. This is likely, because he recorded no buying and selling of any ornamental fish species for the month of December.

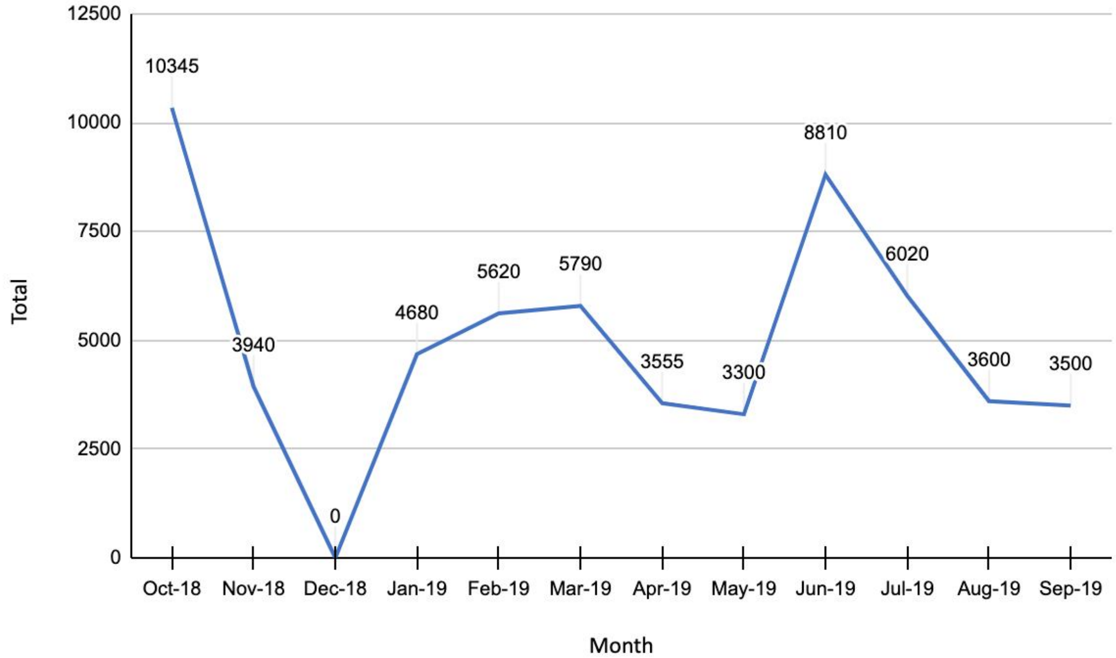

Figure 3. *G. okinawae* total volume bought and sold by month (October 2018 to September 2019).

Purchasing frequency and fisher participation. On average over the one year study period, Trader A purchased *G. okinawae* every 9.7 days. One interesting note is that purchases became more frequent, on average every 3.4 days, during Ramadan (May 6th-June 3rd 2019), when there are religious restrictions about using compressors and diving. Trader B only had two buying and selling transactions that were two months apart (early February and early April 2019). Trader A reported purchasing fish from 24 different fishermen, with 9 of those fishermen selling fish to him 10 times or more. This is out of an estimated total village population of around 1,855 in 2019 (BPS 2020). The highest number of transactions with a single fisher was 23, while there were 6 fishermen with whom he had only a single transaction during the year. The mean number of collecting trips per fisher was 7.5 over the one year study period. On the other hand, Trader B only reported buying *G. okinawae* from two people.

Mortality. Trader A reported that 72 individuals died between the fishermen catching *G. okinawae* and bringing them to him at his home to count. An example of this counting process is shown in Figure 4. Mortality would occur mostly in clusters of 10-20 fish at a time, and based on participant observation, is likely to have resulted from the combination of stress and a fisherman using a dirty container to store *G. okinawae* on the boat, allowing captured individuals to get too hot from exposure to the sun, and/or not changing the holding water often enough. Considering there were a total of 181 transactions (fishers bringing *G. okinawae* to the trader and selling them), only 6 of those transactions reported mortality. That equates to one death per every 792 fish caught, a low mortality rate. However, Trader B had a much higher mortality rate even though he only had a total of two transactions. This recorded mortality occurred after he purchased the fish and before selling them. In the first transaction he purchased 750 fish and sold 700 after losing 50 of them. In the second transaction, he purchased 1,520 and reported selling only 120 of those, with an extremely high mortality of 1,400 individuals.

Figure 4. Counting and husbandry of the yellow coral goby *Gobiodon okinawae* at the trader's house. A. *G. okinawae* being counted and transferred to a "gabus" from a basin, both aerated; B. A close-up of *G. okinawae* in a bowl of similar size to the counting bowl in A. Photographs by Shannon Switzer Swanson.

Trader income. Trader A bought each *G. okinawae* for 1,000 IDR (~$00.07 USD) and sold each for 1,500 IDR (~$00.11) USD, demonstrating that this is a low value species that must be bought and sold at a high volume to make substantial profit. This contrasts with the blue tang *P. hepatus*, which carries a higher market price per individual. In total, Trader A made $5,943.39 USD in sales of *G. okinawae* in one year, with net income of $1,976.19 USD. This income does not account for costs other than purchasing the fish from fishermen. The income was calculated using the average IDR to USD exchange rate for each month in which the data was collected as reported by x-rates.com (https://www.xrates.com/average/?from=IDR&to=USD&amount=1&year=2018).

Interestingly, from survey data, Trader A reported an average income of 2 million IDR or $140 USD per month, which is $1,680 USD per year, less than the profit reported from *G. okinawae* alone. This shows that, most likely, Trader A severely underreported his average monthly income; but also indicates that extra income from *G. okinawae* is significant. In contrast, Trader B bought each *G. okinawae* for the same price but sold each one for 3,000 IDR (~$00.21 USD), and only made a total of $174.66 USD with a net income of $17.04. This low margin is due to the high mortality of his second round of purchasing, where he lost $82.36 USD. This experience may be why he did not continue to attempt to trade the species, considering it too high risk for his trading model.

***Fisher gross income**.* For the fishers involved in the trade, the highest earner, with annual gross income from the goby, before costs, received $998.90 USD. This was the same fisher with the greatest number of transactions with Trader A. This income was more than double the amount of the next highest earner, who totaled $434.70. The mean earning for the year was $165.08 USD, with an average of $19.67 USD per trip. Similar to fisher-buyer relationships in other fisheries, the traders or buyers clearly profit more than the individual fishers, with the buyer earning nearly double that of his highest earning fisher; however, the fishers have the benefit of not having the responsibility of managing the counting, care, and shipping of the fish, but rather dropping them off at the end of the day and immediately being paid.

Discussion. With this first-of-its-kind source-level data, we begin to understand how the fishery for *G. okinawae* operates in the region, what it adds to local livelihoods, as well as consider its potential ecological impacts.

***Benefit to fishers**.* While only 24 fishers participated in the collecting and selling of *G. okinawae*, for those who participated, the species represented another way to diversify their livelihood strategy. Based on observation over the course of the year, as well as the volume-by-month data, our findings suggest that being able to collect goby was especially important during periods of seasonally inclement weather, including "musim utara" or north monsoon, historically during the months of December, January, and February, as well as "musim selatan" or south monsoon, historically during the months of June and July. Additionally, the lead author observed that fishers would choose to collect goby during sporadic days of strong wind, large waves, and/or heavy rain outside of the two rough-weather seasons. On these days they preferred not to travel far for fear of damaging their boats, engines, and fishing equipment as well as for their own safety.

For example, on several occasions, one of the research participants, who was primarily an octopus fisher, attempted to catch *G. okinawae* when he was unable to fish for his target species in further away fishing grounds. In fact, he wished to collect goby on more poor-weather days than the traders were willing to buy them from him. These are important factors to consider when examining the marine aquarium trade (MAT), as understanding how weather influences fishing behaviour is understudied despite being a critical driver of fisher decision-making (Thoya & Daw 2019). Drawing from the lead author's participant observation data, a series of bad weather days was often when fishers who did not usually use destructive practices, such as bombs, would turn to these methods out of frustration and the need to earn income for the day or at least bring fish home for dinner. Therefore, the potential for collecting goby to provide a more sustainable alternative to earn income during poor weather days is significant.

However, the temporal variation in volume does not appear to be wholly weather-related, suggesting that other factors including market demand and religious customs may also be influencing when the yellow goby is targeted. For example, during the month of October the weather is typically calm, allowing fishers to go further afield (EC-PREP 2005; Ambo-Rappe & Moore 2018), and we would hypothesize that fishers would then target higher-value species like the blue tang. However, our data show that the largest volume of *G. okinawae* was collected during this month, indicating that opportunity may also be a factor in goby collection. For example, this period coincides with a reported increase in market demand for aquarium fish in the European Union during the northern hemisphere winter, with retail stores increasing stocks in the two months before Christmas (Pinnegar & Murray 2019). Finally, as noted in the results, there was an increase in frequency of *G. okinawae* collecting and sales (though not in total volume) during Ramadan, when fishers are discouraged from using compressors to dive and tend to make shorter fishing trips to ensure they do not miss the breaking of the fast at sunset and evening prayers. This religiously motivated behaviour modification noted in other predominantly Muslim fishing communities (see de la Torre-Castro & Lindström 2010) may have caused fishers to focus on *G. okinawae*, due to its proclivity for shallow reefs in the nearby sheltered bays and mangrove areas, when they would otherwise use compressors to target higher value species.

Despite this added flexibility and opportunity to diversify target species, one item to note is that a significant portion of the total annual fisher income from collecting and selling this species belonged to a single fisher. This is not necessarily a downside to the trade of this species, but it is notable, as there can be what is know as "elite capture" by fishers with more access to capital and resources, who can monopolize a trade (Saito-Jensen et al 2010). On the other hand, it could simply reflect that this fisher recognized the opportunity to catch this species earlier than others, and, therefore, learned the best collecting locations as well as gained proficiency in his collecting technique before others joined in the emergent fishery. In fact, there is reason to think the collecting and selling of *G. okinawae* may provide relatively equitable access, because it requires minimal specialized equipment compared to other aquarium species. This is true relative to *P. hepatus*, which most fishers in the region catch using cyanide and diving compressors – the former which must be secretively accessed due to its illegality, and the latter which requires significant capital to purchase and maintain.

Benefit to traders. The volume and profit data show that Trader A, who lived year-round in the source village of Toropot, was far more involved in the buying and selling of the goby and had more success when comparing volume, income, and mortality with Trader B. Because Trader A was able to buy fish directly from the fishers at the end of their collecting sessions, he had greater control over their care and maintenance as he prepared to ship them onward in the supply chain. He was also able to ship them quickly, typically within 24 hours of the fish being collected.

On the other hand, Trader B lived on the main island of Banggai and visited the source village sporadically depending on the weather and how many aquarium fish his sources had accumulated. Therefore, he was less nimble in purchasing and shipping. Based on how he reported his purchasing, with a large volume of fish from one person, and with only two transactions total, it seems that his sources may have acted as local middlemen, purchasing smaller amounts from individual fishers and selling them on to Trader B. This purchasing arrangement could possibly explain the high mortality rate of the second transaction, as *G. okinawae* cannot be stored in net pens under homes as is practiced with blue tang, which allows fresh seawater to filter in and out. The goby's small size makes it imperative to move the fish through the supply chain quickly, giving a resident trader, like Trader A, a distinct advantage with trading this species. This may be seen as a positive attribute of the goby trade in the area, in that it would be difficult for non-local traders to capitalize on collecting the species and divert benefits away from residents of the source area.

Costs for fishers vs traders. As mentioned in the results, the reported profits do not take into account costs for the fishers or traders, beyond the purchase cost of the fish for the latter. Additional costs for fishers include fuel, food, time, and equipment. However, catching yellow gobies requires less sophisticated equipment than catching *P. hepatus* and generally less fuel, as the species typically inhabit the nearby shallow lagoons, which means fisher costs are likely lower for *G. okinawae*. Trader costs and overheads beyond purchasing the fish are greater than the costs incurred by the fishers. They include buying clean, large, and new styrofoam containers for each shipment, additional packing materials like tape, aeration equipment, cellular data for communicating with their buyers, and shipping. However, shipping is more straightforward for a small species like *G. okinawae* than for a larger, higher value species like *P. hepatus*, which need to be individually bagged and aerated once on the main island of Banggai, in order to be shipped safely to Luwuk on mainland Central Sulawesi. It is therefore likely that, similar to the fishers, traders' costs are lower for the goby than for the blue tang.

Sustainability. In theory, we argue that collecting *G. okinawae* presents a relatively sustainable source of income due to the low vulnerability ranking of the species in a recent Productivity Susceptibility Analysis of 72 reef fish stocks (see Dee et al 2019). Based on 10 life history attributes used to estimate the species' productivity and 12 catchability, management, and fishing practice attributes to estimate susceptibility to overfishing, *G. okinawae* was found to be the least vulnerable of all 72 species (Dee et al 2019). This is promising, especially compared to targeting *P. hepatus*, which the lead author observed primarily still being caught in the region using cyanide, which is thought to be unhealthy for reefs, for the target animals, and for human health (Rubec 1986; Madeira et al 2020).

However, it is important to note that fishers will gravitate towards the most efficient way of collecting a species, which, as observed in the case of *G. okinawae*, can include dislodging large pieces of branching coral to shake the goby into their nets. If done too often or by too many fishers, there is potential to destroy the habitat of the goby and therefore decrease its ability to reproduce and maintain a viable population. This practice also violates several Indonesian laws (e.g. Laws UU 5/1990; UU 27/2007; UU 32/2009; UU 45/2009; UU 32/2014) prohibiting damage to corals. While trampling such as that likely to occur during the collection of *G. okinawae* can cause some damage to corals (Williamson et al 2017), uprooting coral colonies is likely to cause far higher levels of coral mortality as well as a rapid loss of structural complexity and habitat niches affecting the coral reef community. Severe damage reportedly due to a similar practice (breaking off table corals and upending them to collect ornamental fish) was observed during a survey in the Bokan Kepulauan area in 2012; according to local people the fishermen were roving fishers (thought to be from Bali or East Java) and the fish species collected were not known (Samliok Ndobe and Abigail Moore, unpublished data). This practice of uprooting coral colonies could therefore not only seriously threaten the sustainability of the resource but also cause increased conflict and tension between regional law enforcement and the fishing community.

A comprehensive training program led by an NGO that already works in the region (e.g. LINI) could potentially partner with regional and local government entities and other concerned stakeholders to help the community develop a sustainability ethic that encourages fishers to think over a longer time horizon about the health of the goby habitat. Enculturing a broader ethic of care could not only address the issue of coral uprooting in the case of collecting *G. okinawae,* but also other fisher behavior that damages reefs in the area. For example, the use of metal crowbars to pry abalone (*Haliotis asinina*) from the reef (EC-PREP 2005; Moore & Ndobe 2008; Ndobe et al 2013, 2018) and entangling coral in nets when catching food fish.

Also of note is that other handling and care knowledge is important to reducing mortality of captured fish (Militz et al 2016). For example, when the first author accompanied the octopus fisher to catch goby, as noted earlier, he unknowingly used a gabus that had been contaminated with something toxic to the goby. This resulted in over half of the fish he caught dying, all of which he discarded. This incident illustrates the need for fisher knowledge of proper handling and care during the collecting process to prevent unnecessary mortality, thereby also reducing lost income. This knowledge may be gained over time, passed on by the trader, who has a vested interest in reducing mortality, or could also potentially be part of a formal training program.

Limitations and future research. Here we present one year of data, however more longitudinal data are needed to understand whether this was a typical year, and if any of the patterns we observed hold over time. Also, while we spot checked the data as discussed in the methods, we did not verify trader counts of fish bought and sold. We were also unable to verify the mortality reports and suspect that mortality is higher than reported based on both potential unreported mortality as well as the fact that the data capture just one stage at which mortality may occur. For example, it is likely, based on observational data, including the incident mentioned above, that the fishers threw back any individuals that died after leaving the fishing site and prior to reaching the buyer's home to sell the fish. Furthermore, there is likely additional mortality during the crossing from the outer island to the main island of Banggai, then during boat transport to Luwuk, continuing up the supply chain through export and eventually import. While this mortality does not affect fisher and trader income, as they have already passed the fish on, it would be helpful to know this mortality to further understand the sustainability of the species on a larger scale within the aquarium industry. Lastly, it would be helpful to examine buying and selling data of *P. hepatus* during this same time period in order to better understand how trade of the two species interacts.

Conclusions. While more still needs to be understood about the trade in yellow coral goby (*Gobiodon okinawae*) in the Banggai Laut District, this data provides initial insight into the trade of the species. We demonstrate how the yellow goby *Gobiodon okinawae* may provide an additional source of income that allows fishers and traders to diversify their target species with one that is cited as having low vulnerability to overfishing and that is located in areas close to home. These fishing grounds remain accessible during both inclement weather days as well as longer seasons of bad weather that limit their ability to catch other target species, helping fishers continue to earn some income during challenging circumstances. The maintenance of coral cover, especially branching acroporids, is vital for this obligate coral-dwelling fish. In particular, attention seems necessary to the fishing methods employed in order to minimize damage to corals and other benthic organisms. Overall, we conclude that this species represents a promising addition to the aquarium fishery in the region but thoughtful management should still be considered to ensure that the benefits the species provide remain.

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