

The mangrove crabs of Pohnpei Island, Federated States of Micronesia: A timely intervention to ensure sustainability of a favoured resource

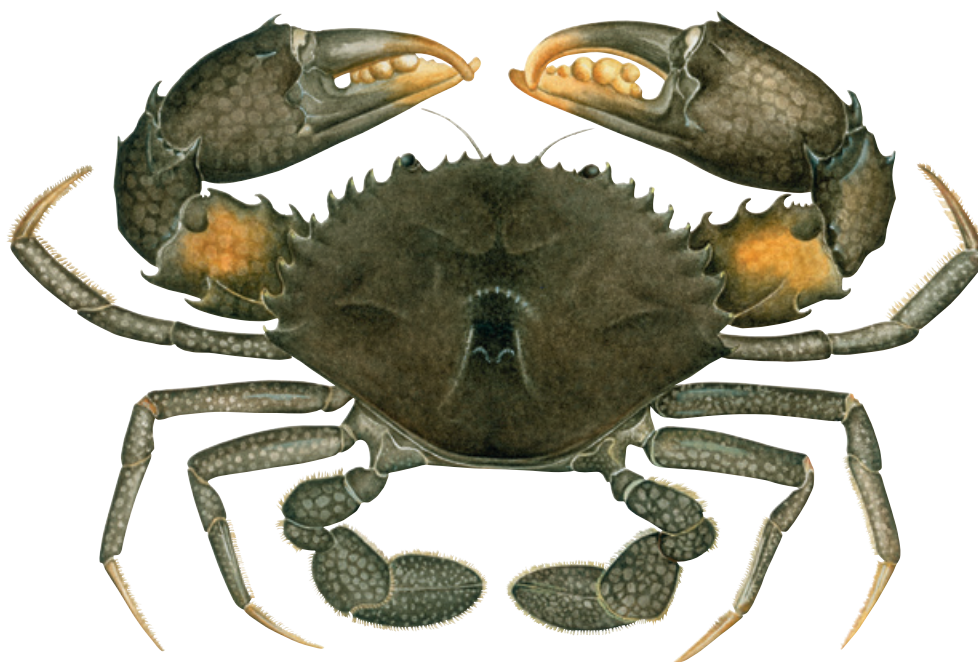
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Introduction

The mud crab or mangrove crab, *Scylla serrata*, is a highly desirable crustacean species that is widespread throughout the Indo-west Pacific region, where it lives in close association with mangrove ecosystems (Fig. 1). Genetic analysis has demonstrated that there are at least three distinct stocks of mud crabs in the region: western Indian Ocean, eastern Australia and the tropical Pacific Ocean, and northwestern Australia (Fratini et al. 2010). The larvae of *S. serrata* can drift at sea as part of the plankton for up to 75 days, enabling them to colonise habitats far from the home of their parents, resulting in genetically well-mixed populations.

The life cycle of these crabs is complex, involving an extended period in the planktonic phase where they go through five

developmental stages before settling into habitat close to mangroves. As they grow, individuals move incrementally farther into the mangrove system. Sexually mature females undergo long-distance migrations of up to 90 km, to off-shore waters to spawn and renew the cycle (Fig. 2). Crabs can reach maturity in as little as 12–18 months in tropical latitudes but can take as long as 24 months in more temperate locations. Sexual maturity for *S. serrata* also occurs at different sizes throughout their geographic range. For example, male crabs in South Africa reach sexual maturity at a carapace width (CW) of 11–12 cm, compared with Pohnpei, which is quite close to the equator, where they are a full 1 cm larger at 12–13 cm CW (see Table 2 in Alberts-Hubatsch et al. 2015). Mud crabs typically only live for a maximum of three to four years, such that constant recruitment is necessary to keep the population replenished and stable.



The mud crab or mangrove crab, *Scylla serrata*. (illustration Rachel O'Shea, SPC)

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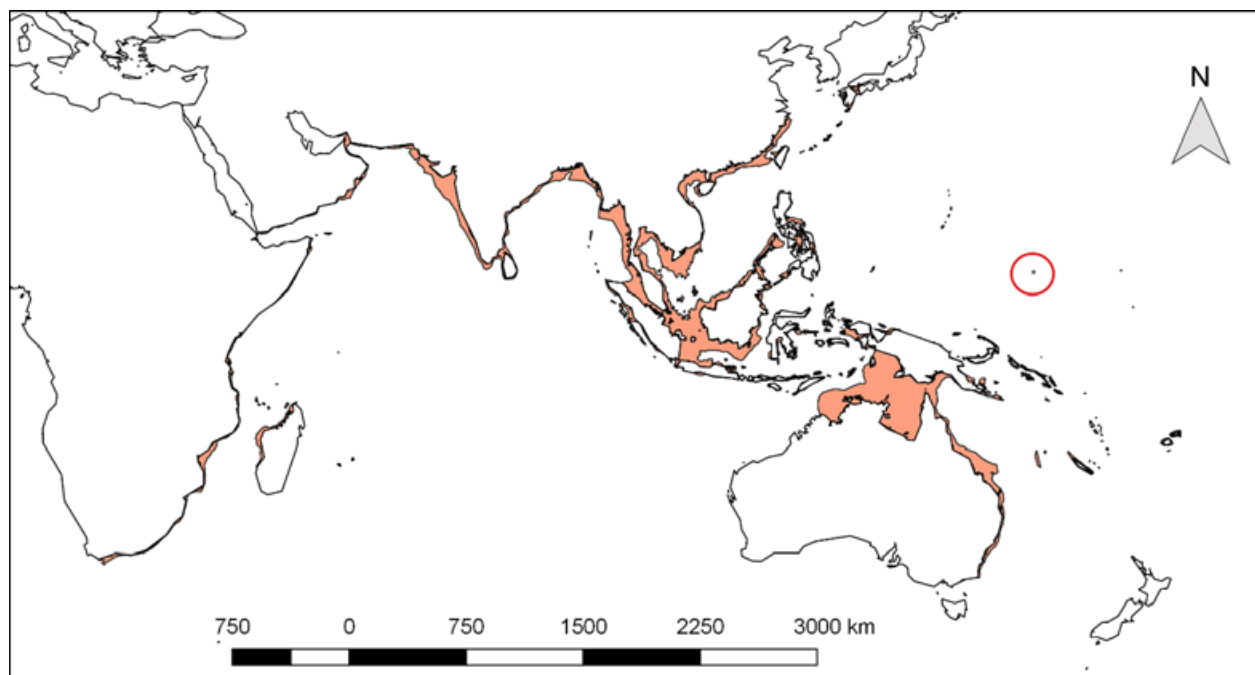


Figure 1. Global distribution of the mangrove crab *Scylla serrata*. Red circle indicates the location of Pohnpei. (Map details from FAO, GeoNetwork website)

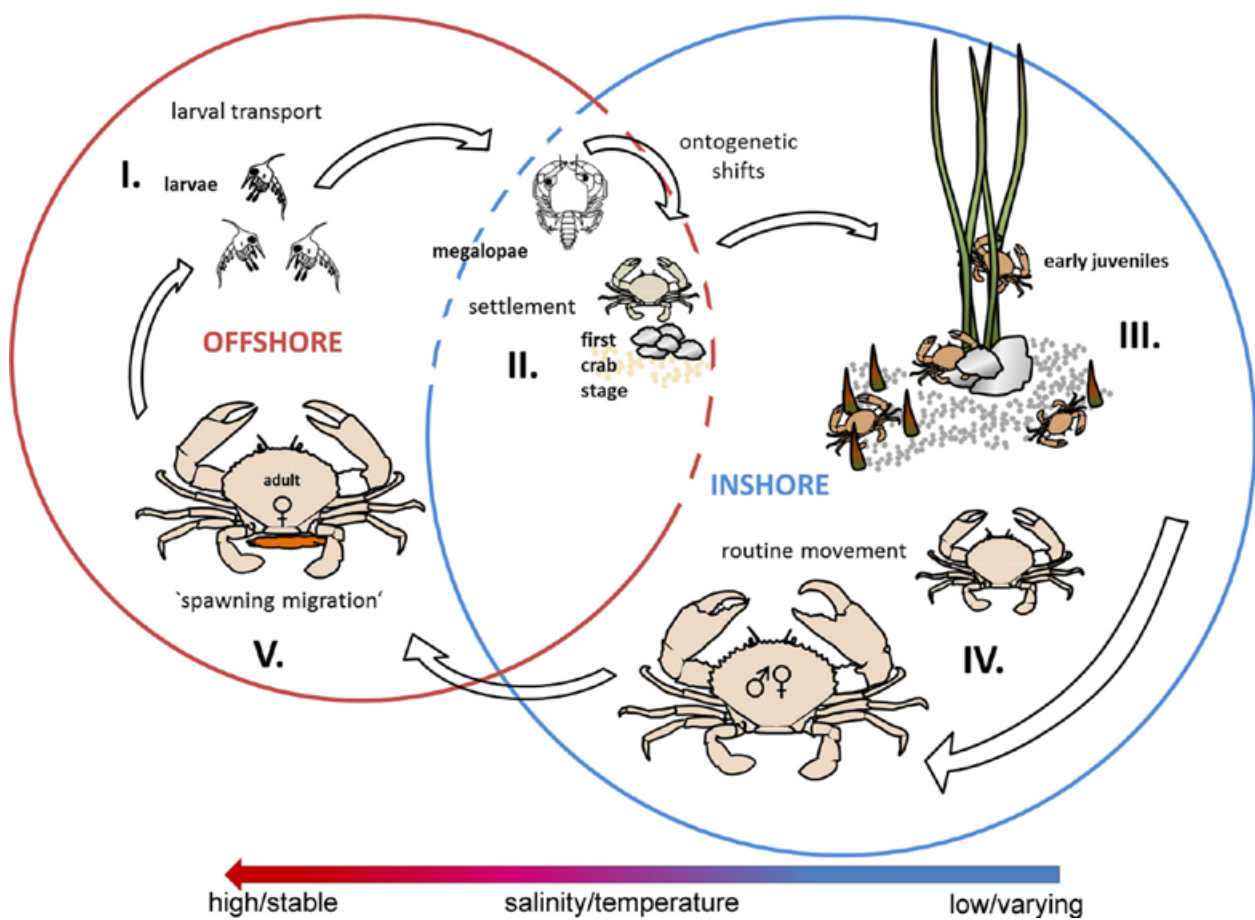


Figure 2. The life cycle of the mangrove crab *Scylla serrata*. Salinity and water temperature are influential throughout the life cycle. (Source: Alberts-Hubatsch et al. 2015)

The timing and extent of spawning and recruitment varies with latitude. In cooler climates, spawning is constrained to the summer months, while closer to the equator where temperatures are less variable spawning can occur year-round.

Mature crabs are found in all areas of the mangrove ecosystems that they are closely associated with. Where significant mud banks exist, they dig holes up to 2 m deep for sheltering in. They are also found within the root systems of mangrove trees, in hollows of more mature trees, and on the mud and seagrass flats that often exist adjacent to and within mangroves and estuary systems. While capable of making significant migrations, as evidenced by female spawning behaviour, tagging studies have shown that most crabs move less than a few kilometres from where they are initially captured (Hyland et al. 1984; Bonine et al. 2008).

Mud crabs are a highly desirable seafood. Their sweet, delicate flesh is highly sought after by consumers who are willing to pay a high price for a meal of these crustaceans. Prices for wild-caught, live mud crab can be as high as AUD 80 per kilo in Australia and Japan. Indonesia has the largest catches of mud crabs, with 64,602 tonnes caught in 2017, and Singapore being a primary export destination. Australia by comparison had a total commercial catch of ~1500 tonnes in 2018, while Thailand's catch was estimated at 412 tonnes in 2017 (Aldon and Nagoon 1997; FAO statistics [<http://www.fao.org/figis/servlet/TabSelector>]; Shelley 2008; www.fish.gov.au/report/155-MUD-CRABS-2018). Most countries that report their catches to FAO show a declining trend in annual harvests.

The increasing global demand for mud crabs is placing enormous pressure on wild stocks, driving calls for more investment in farming these species. However, despite progress in the culture of mud crabs in Japan, Vietnam and the Philippines, most culture facilities still rely heavily on wild-caught crablets and juveniles, with culture successes remaining low and inconsistent (Waiho et al. 2017). Considerable research is still needed before larval culture and rearing of mud crabs becomes a viable alternative to the harvesting of wild stocks.

While the largest populations of mud crabs are found in countries with the most extensive and mature mangrove ecosystems, such as those throughout Southeast Asia and Australia, there are nevertheless well-established mud crab populations throughout many smaller countries that contain mature mangrove forests, including many Pacific Island countries and territories. Within the Federated States of Micronesia (FSM), all four states – Yap, Chuuk, Pohnpei and Kosrae – contain mature mangrove stands with resident populations of mud crab. Pohnpei, however, has significantly more mangrove area (~5500 ha) than the other states combined (Yap, ~1100 ha; Chuuk, ~300 ha; Kosrae, ~1500 ha) (Smith 1992).

Although the mangrove systems of small island states such as FSM are not capable of producing enough crabs to be a

major contributor to gross domestic product, this resource is nevertheless important as a high-value product within local markets. The animals can be kept alive out of water for up to a week if stored properly, which is an advantage in areas where post-harvest processing and transportation facilities may be less than adequate. Setting up a crabbing operation requires minimal capital investment and as the product is highly sought after by the tourist and restaurant trade where it commands a high price, it provides ready cash for artisanal fishers and their families. Mud crabs from Pohnpei are considered particularly tasty in the greater region and, hence, are in high demand.

Previous research into mud crab populations within FSM focused on Kosrae and, to a lesser degree, Pohnpei. These reports and papers provide substantial insights into FSM's mud crab populations, and served as a baseline for the 2018 assessment of Pohnpei's mud crab populations. Male mud crabs in Kosrae display biological and ecological characteristics similar to those reported elsewhere: they are significantly larger than females, their movements are restricted, their maximum size is 20–24 cm CW, and their maximum lifespan is 3–4 years (Bonine et al. 2008). Observed differences in the size structure of crab populations from different parts of the island were correlated with variable harvest pressure, reflecting the distribution of the human population and location of emerging commercial harvest operations (Bonine et al. 2008; Ewel 2008).

Prior to the 2018 survey, Pohnpei's mud crab populations were last studied in 1977–1978, over 40 years ago (Dickson 1977; Perrine 1978). These older studies nevertheless identified similar biological and ecological parameters to the studies on Kosrae's crabs, undertaken 20 years later. They also highlight strong spatial differences in the size structure of mud crab populations between locations where crab trapping occurred. These differences correlate with the density of people living nearby and the spatial extent of the local mangrove forests, again similar to the results from the Kosrae studies. It was concluded, however, that Pohnpei's mud crab populations at that time were not being overexploited and that fishing restrictions were unnecessary.

Forty years later, FSM's human population has risen by ~ 70% and the pressure on natural resources is high. Responding to increased concerns from constituents about an apparent long-term decline in the abundance and size of mud crabs, a national senator requested help from the Pacific Community to undertake an assessment of the health of Pohnpei's mud crab stocks, and to provide advice on the most effective management strategies.

To obtain the information necessary to assess the health of Pohnpei's mud crab stocks, the following objectives were undertaken:

- An extensive island-wide trapping programme within the major mangrove areas around Pohnpei.

- Surveys of local fishermen to understand catch and effort, and spatial distribution of effort.
- Surveys of local fish markets to understand volume, size and price of mud crabs being sold, and to whom.
- Surveys of exports through the local airport to better understand the volume of mud crabs being exported from Pohnpei.
- Review of current data collection, storage and reporting activities by national and federal government agencies.
- Review of current legislation regarding the exploitation of mud crabs.

Methodology

Data needed for the assessment were allocated across five separate areas encompassing fisheries-independent trapping surveys, market surveys, fisher creel surveys, airport surveys and export studies (Fig. 3).

Trapping

Trapping locations were chosen to ensure coverage around the whole island and, where possible, to overlap with areas that were trapped by Perrine in 1978 (Fig. 4).

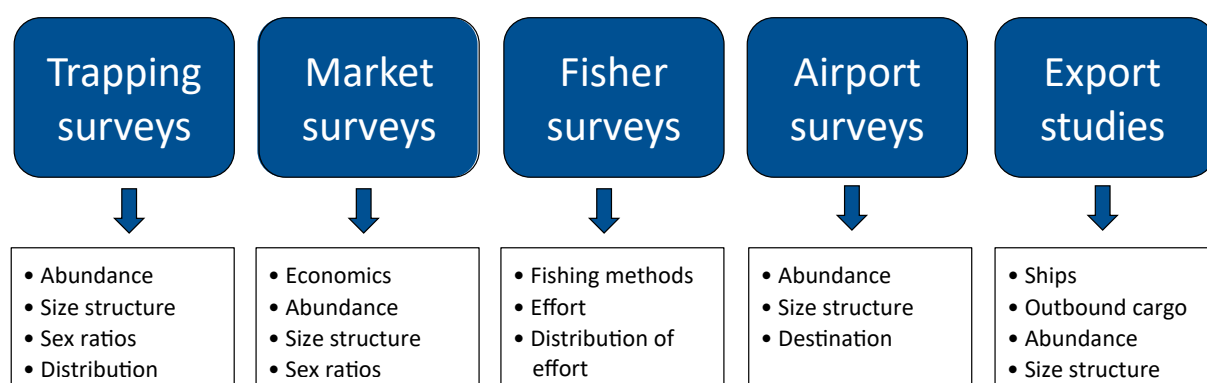


Figure 3. The five areas where data collection was focused, and the range of outcomes that can be derived from each data collection method.



Figure 4. All locations on Pohnpei Island where trapping was undertaken (orange crosses). Yellow polygons represent mangrove protection areas.

Thirty traps of proven design for maximising mud crab catches, were purchased (Fig. 5).

At each general location three groups of 10 traps were set upstream, downstream and outside the river mouth. This amount of replication was reduced after the first week of trapping because of the loss of a number of traps. Subsequent groups consisted of 7, 7 and 6 traps set at least 50 m apart to avoid overlap in the catching zone of individual traps. Traps were baited with 500 g of skipjack tuna, which was replaced every 24 hours, or less if the bait was taken within this period. Traps were fished for a minimum of three days, or more if catches did not decline during this period.

Individual traps were checked approximately every 10–12 hours on a morning and evening schedule, although spring low tides sometimes made it difficult to stick to this schedule. The sex, weight and CW of all mud crabs caught were determined and recorded. The crabs were then released after painting an identifying number on their shell using a tippex pen and attaching a coloured cable tie to the base of one of their swimming legs (Fig. 6). Crabs were marked to distinguish them from new crabs that were caught during subsequent trappings. Each time, new crabs were marked while previously marked crabs that were re-caught were noted on the datasheet and returned to the water. This mark-and-recapture programme provides data from which estimates can be calculated for the total number of adult crabs inhabiting a particular mangrove ecosystem.



Figure 5. Fisheries officers from Pohnpei and Kosrae, and Conservation Society Pohnpei staff, assembling crab traps and bait bags prior to beginning the trapping programme. (image: Andrew Halford, SPC)



Figure 6. A captured crab has been marked with the number '11' using a tippex pen, and its rear left swimming leg has a blue cable tie attached to aid with identification if recaptured. (image: Andrew Halford, SPC)

Market surveys

Three individual markets were identified as the main buyers and sellers of mud crabs in Kolonia, Pohnpei's capital: H&D, Ellens's and Saimon's. Market stalls were visited at least once a day to check on the presence of crabs; and, with the permission of the stall owner, all crabs for sale were weighed, measured and their sex determined (Fig. 7). The buying and selling of crabs can happen at any time of the day but in general catches of crabs were sold to the market stalls at the market's opening and evening times, with sales occurring at any time crabs were available.

Fisher surveys

Identifying individual fishers to interview was a time-consuming process, given the remoteness of many of the main fishing areas and the inability to contact individuals by phone. Finding interviewees required driving to individual villages and speaking to people until we found someone willing to participate in the survey. We were eventually successful in interviewing 12 fishermen over the course of one month (Fig. 8). Interviews were conducted using standard creel survey questions that seek to understand the effort, cost and outcomes of targeting mud crabs.



Figure 7. Measuring mud crabs at Saimon's Market. (image: Andrew Halford, SPC)



Figure 8. Interviewing a mud crab fisherman. (image: Andrew Halford, SPC)

Airport surveys

Because they are highly prized throughout the region, many travellers leave Pohnpei with mud crabs they purchased from the local markets. Regulations allow the export of 15 mud crabs per individual per trip; regular flights out of Pohnpei, therefore, could potentially have significant numbers of mud crabs onboard. After gaining permission from all relevant government departments, and the airlines, we were able to check the coolboxes (a.k.a. ice chests) of travellers who were taking crabs out of Pohnpei, and to measure, weigh and determine the sex of all crabs observed.

Other

Anecdotal evidence from numerous sources identified another potentially significant source of mud crab sales and transactions: the sale of mud crabs to individuals from longline and purse-seine vessels moored in the harbour. Formal interviews were not possible with anyone directly involved with this process, so information was gathered from the observations of customers visiting the markets and general discussions with market stall personnel.

Results

Trapping

A summary of all mud crabs trapped in 2018 revealed a 12% bias in favour of male crabs caught, for a total of 190 males and 147 females caught. Mean CW was effectively the same for males and females at 14 cm (Fig. 9).

When the trapping results are grouped by location (Fig. 10), clear differences can be seen in the size structure and abundance of the crabs. Laiap in the south had the largest mean size of male and female crabs, although the total number of crabs caught was only 16, while Madolenimh in the east had the smallest crabs but the total number of crabs caught was 174.

Market surveys

In total, 307 crabs from the markets were measured, with an overwhelming majority of these being males (70%). The median CW was 7 mm larger for males, and mud crabs from the markets were consistently larger than the average size of crabs caught through our trapping programme (Fig. 11).

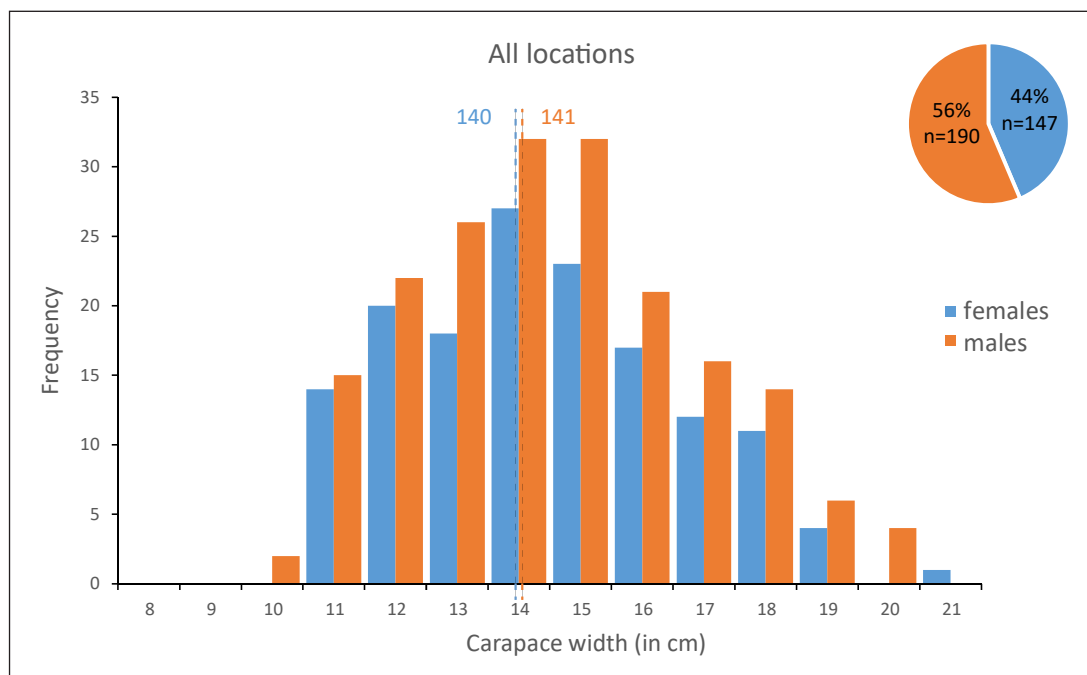


Figure 9. Size structure and overall sex ratio of all mud crabs captured.

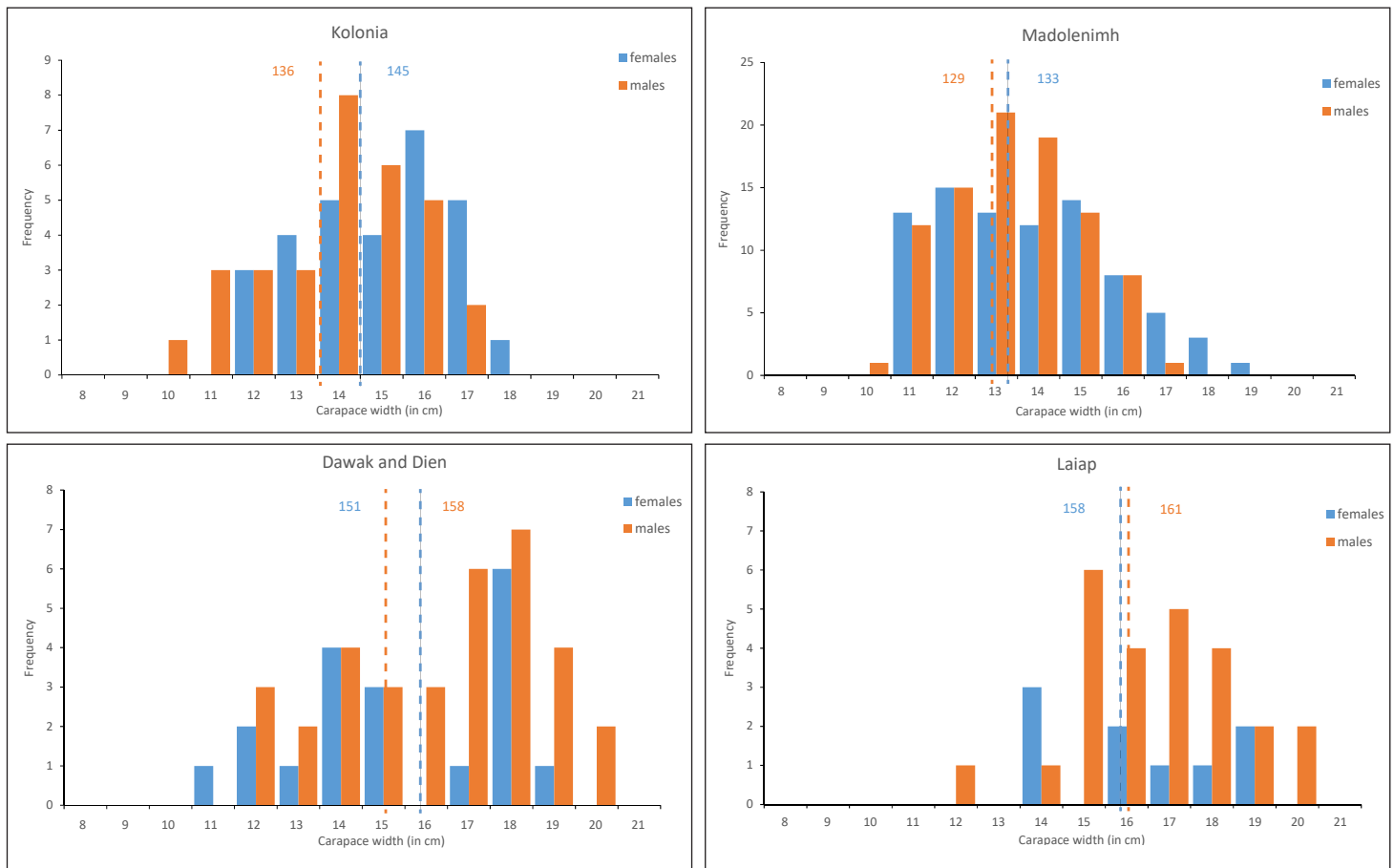


Figure 10. Size structure of male and female mud crabs from four locations around Pohnpei. Vertical dashed lines indicate median carapace width for each sex.

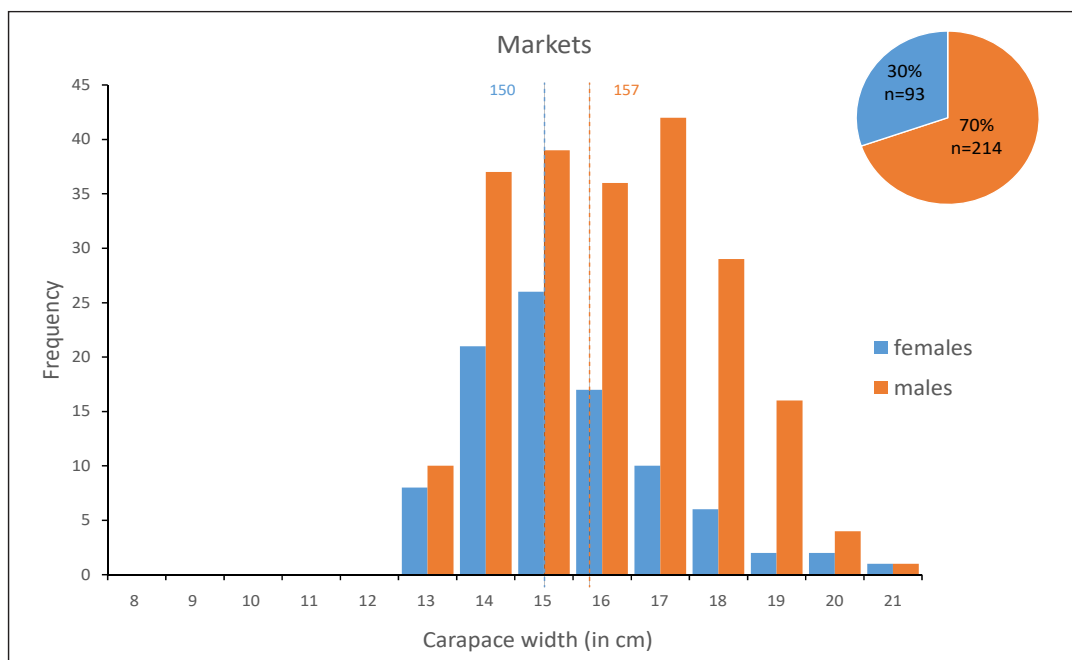


Figure 11. Size structure and overall sex ratio of all mud crabs surveyed at markets.

Fisher surveys

We conducted 12 interviews with mud crab fishers: one woman and 11 men. Fishers were from all parts of Pohnpei Island, with the majority coming from the south and west regions where most crab fishing occurs (Fig. 12). A variety of fishing methods were used, with trapping the most common followed by hand collection by walking through the mangroves, and snorkelling.

Airport surveys

Six flights were checked for the exportation of mud crabs. Four of the flights were west bound to Guam and had a total of 33 crabs. The other two flights were east bound to Honolulu, and had no crabs. It should be noted that an AirNiugini accident at Chuuk had a significant impact on passenger numbers flying during the time we were surveying outgoing flights from Pohnpei. We were also informed by airline staff that it was not a busy time of the year for people travelling into and out of Pohnpei.

Other surveys

Anecdotal information suggests there is a regular trade in mud crabs between fishers and markets, and crew onboard foreign fishing vessels. We were unable to conduct interviews to gain a more detailed understanding of this aspect of the fishery, although informal discussions with fishers

and market sellers, and personal observations at the markets, indicated that up to 80 crabs may be sold by the markets at one time, and that the crabs are regularly purchased by foreigners from foreign fishing vessels. The frequency of these purchases is dependent on the flow of crabs to the markets, but if catches are good then these purchases may be conducted multiple times a week.

Discussion

Our surveys indicate that the median size of mud crabs around Pohnpei is smaller than it was in 1978 when the last surveys were conducted. The median size of all crabs trapped in 2018 was around 15 cm CW compared with a median CW of about 16 cm in 1978. This is not surprising given that FSM's population has increased by 70% since 1978 and there are more people fishing for mangrove crabs now. There is no minimum size limit for harvesting mud crabs in Pohnpei, with management regulations limited to a prohibition on taking female crabs that are carrying eggs, and exporting crabs for commercial purposes. People are allowed to take 15 crabs out of the country for personal use on any given trip, upon purchase of a permit to do so.

When mud crab catches were summarised by location there were clear differences in the number of crabs caught and the median size of males and females. Those areas with the largest crabs have smaller populations of people living nearby

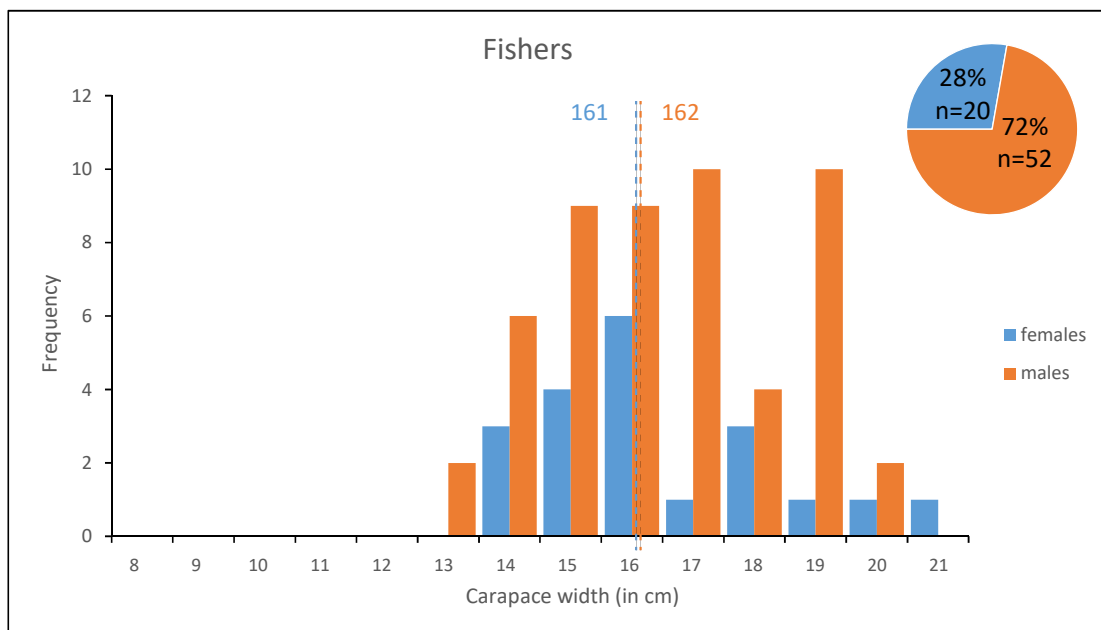


Figure 12. Size structure and overall sex ratio of all mud crabs caught by interviewed fishers.

and the largest areas of mangrove forests, which is a pattern consistent with previous work in the region. Male crabs were also larger than females in these locations. In contrast, those locations closest to human population centres, such as Kolonia, had much smaller crabs overall, and the median size of male crabs was smaller than female crabs, which is not typical in an undisturbed population. These locations are clearly under greater fishing pressure, where more males from the population are being captured than females.

Crabs in the markets were 1 cm greater in median size, at 15–16 cm CW, than the overall crab population, as determined through trapping. The ratio of males to females was also more skewed towards males than in the general population. This indicates that fishing is preferentially targeting larger crabs in the population, which typically are males. This makes sense economically because the largest crabs fetch the most money.

The median CW size of crabs at the markets in 1978 were 15–16 cm for females and 16–17 cm for males, with a 20:80 ratio of females to males. In 2018, the median CW size was 14–15 cm for females and 15–16 cm for males with a 30:70 ratio of females to males. This indicates a longer-term reduction in the maximum size of male and female mud crabs over time, which is a primary indicator of a response to fishing pressure.

The median CW size of females in the population at around 14 cm is above the estimated width at maturity, indicating that there is still adequate recruitment occurring within Pohnpei's mud crab population. However, there has clearly been a long-term decline in the size and abundance of mud crabs around Pohnpei, with changes most evident in the male population. This reality is also perceived by the people fishing for crabs, with 9 of the 12 fishers interviewed stating that they believed the number and size of crabs was declining.

Our surveys – both in-water and at the markets – give us a good general understanding of the structure of crab populations around Pohnpei, which show signs of overfishing. While too many crabs being harvested is the primary reason for the current situation, what is less clear is the primary drivers of overfishing. A larger population will inevitably lead to more fishing effort but there are also external drivers that can inflate the level of fishing above what a local economy would normally undertake. In this study the one area we have not been able to quantify is the trade in crabs between fishers and crew aboard foreign fishing vessels. Current laws do not prohibit individuals from purchasing as many mud crabs as they like from the markets, although one person is only allowed to take 15 crabs out of the country, and only with a permit. Anecdotal evidence indicates that far more crabs than could reasonably be eaten at any given time are being bought by crew aboard foreign fishing vessels. While this trade from the markets to the boats is legal, unless they are being exported, there is also anecdotal

evidence that fishers are dealing directly with the boats. This trade pathway does not have any of the checks that exist through a more formal market system, and can easily encourage increased fishing intensity and the retention of smaller crabs. Any attempts at instigating effective management plans will not be effective unless this area of trade in crabs is documented and well understood.

A more detailed analysis of the data collected within this study is still ongoing and will help Pohnpei better understand the current situation with regard to the health of its mud crab populations. There is clearly a need for an improved management regime to ensure the sustainability of this favoured resource. The issues encapsulated within this fishery are typical across the Pacific, and lessons learned elsewhere will help inform management protocols to be implemented in Pohnpei. The important first step is recognising that there is a problem, and this has already been acknowledged. The equally important second step of collecting data to inform decision-making is being carried out. There are, therefore, no impediments to introducing effective management plans; the challenge is to implement them as effectively as possible.

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The hardworking team of fisheries officers from Pohnpei and Kosrae without whom the mud crab survey would never have been possible. From L-R, front: Anderson Tilfas, Ryan Ladore, Sam Isaac; back: Dwight Damian, Itaia Fred, Jonathan Dewey. (image: Andrew Halford)

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