The Shallow-water Echinoderms of Kosrae

Results of a Survey Performed 22 February to 7 March 2008, Including a Stock Assessment of Commercially Valuable Species

A Report Prepared for the Director of KIRMA, Kosrae State, Federated States of Micronesia

Submitted by

Alexander M. Kerr, Sun W. Kim and François Michonneau

University of Guam Marine Laboratory
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Kulo!

EXECUTIVE SUMMARY

Kosrae is currently being targeted by at least one foreign buyer of dried and processed holothuroids (sea cucumbers), called beche de mer. The Kosraean government has realized the danger of overharvesting this valuable resource and is currently seeking to develop a management plan that will permit a sustainable level of harvesting. We were invited to perform a preliminary stock assessment and provide recommendations for a plan. In 14 days of surveying between 22 February to 7 March, we surveyed 21 sites around the island. The most valuable species seen were *Holothuria* (*Halodeima*) *atra* (trade name: lolly fish), *Stichopus chloronotus* (green fish) and *Actinopyga mauritiana* (surf red fish). A total of 40 taxonomic units attributable to species of holothuroids have now been identified from Kosrae's waters. We also uncovered and additional 34 species of other echinoderms: 8 echinoids (sea urchins), 11 asteroids (sea stars), 11 ophiuroids (brittle stars) and 4 crinoids (feather stars). At least four (10%) of the holothuroids are in all likelihood new to science and formally undescribed. Based on our brief survey, our preliminary recommendations for a beche-de-mer management plan include: 1) Institute a moratorium on fishing until a management plan is in place. 2) Conduct an inventory of the island's commercially valuable species. 3) Institute minimum harvestable lengths for each species. 4) Institute temporary closures to increase stock size and value. 5) Increase public awareness of the value of reef resources, including beche de mer. 6) Continually assess the effectiveness of the management plan and modify it when necessary. We discuss all these measures at greater length in the final report.

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INTRODUCTION

In early 2008, we were contacted by the Kosrae Conservation and Safety Organization and the Director of Kosrae Island Resource Management Authority (KIRMA), requesting assistance with surveying holothuroids (sea cucumbers) on Kosrae. We were delighted to assist and requested that the proposed survey form part of our U.S. National Science Foundation-sponsored efforts, in collaboration with other holothuroid taxonomists worldwide, to document the global diversity of aspidochirote holothuroids inhabiting coral reefs. We were informed that at least one foreign buyer had approached the governor about export of processed beche-de-mer.

From 22 February to 7 March 2008, we surveyed the holothuroids and other echinoderms around the island of Kosrae. In sum, during this period, we

- surveyed 21 reef sites around the island for their echinoderm fauna,
- assembled a checklist of the island's echinoderms,
- collected and preserved voucher specimens of each species,
- photographed vouchers or representative specimens of each species,
- recorded the population size structure of commercially valuable species of holothuroids,
- taught methods of stock assessment to KIRMA personnel,
- interviewed stakeholders to learn their concerns about the development of a beche-de-mer industry,
- presented a seminar to the Ninth Kosrae State Legislature on our preliminary findings and, finally,
- distributed a preliminary report that included preliminary recommendations about safeguarding holothuroid resources, to the Governor, Director of Resources and Development and stakeholders.

At least three other types of work products also should be anticipated, with various timelines to completion:

- A final report with full management recommendations. This should take about one month to complete from the end of the fieldwork.
- An illustrated field guide to the island's holothuroid fauna, primarily as a tool for personnel at Marine Resources. This should take about six months to complete.
- Peer-reviewed scientific publications, to include, minimally, the first comprehensive faunistic treatment of the island's echinoderms and the formal taxonomic description of at least one species new to science. These publications will be completed over the course of one to two years.

The following report outlines a simple method for stock assessment and provides several suggestions for managing beche-de-mer based on our analysis of the data and the published literature. Following this, we provide a provisional checklist to the island's echinoderms, then discuss the scientific significance of these findings. The term "provisional" indicates that the checklist consists of identifications of specimens made in the field. Hence, a few of the designations will, in all likelihood, change, or in instances where a species could not be immediately assigned, even provisionally, species' identities will be clarified after full laboratory examination. Still, most species designations provided here are trustworthy and thus, on whole, the list is useful for scientific and public discussion of Kosrae's echinoderms, particularly holothuroids, now under harvesting pressure. Indeed, as far as we know, this is the first attempt at a comprehensive compilation of Kosrae's echinoderms.

METHODS

Site selection

Sites were selected around the island for the presumed high density and species richness of holothuroids. GPS coordinates of each site were recorded. Most major shallow-water marine habitats were investigated, including reef flats, “blue holes,” forereef slopes to 25 m depth, seagrass beds, channels and areas adjacent to mangroves. Given the time constraints, we eschewed mangrove channels, rivermouths, steep drop-offs and elsewhere with little accumulation of well-sorted sediment, since such areas, while in some cases having a possibly rich echinoderm fauna (e.g., crinoids and dendrochirote holothuroids in the case of drop-offs), were likely to have few commercially valuable holothuroids, one focus of the survey.

Stock survey

Divers performed counts of commercially valuable species of holothuroids using timed haphazard swims, usually between one or two hours. In addition, divers recorded the undisturbed lengths of animals *in situ*. This approach was reasoned superior to transects, quadrats or manta tows for several reasons. First, the usual methods are time intensive and our mandate was to perform a large-scale survey in a limited period. Second, our approach also estimated an important quantity of interest to fisheries managers: catch per unit effort, the number of animals that a fisher might collect per unit time. Moreover, the method can easily be used by villages to monitor their own stocks. Finally, information on length can be translated into initial management recommendations about minimum harvestable size per species.

Figure 1. Survey sites around Kosrae. Sites are numbered according the table in Appendix 2.

Calculating minimum harvestable lengths

We will calculate minimum harvestable lengths for each abundant species based on the mean length of the sampled individuals. The object of calculating this quantity is to preserve stock in proportion to a conservative percentage of its reproductive capacity. The latter phrase essentially refers to the total number of eggs produced by a stock. Amesbury (1996) suggests conserving 50% of the reproductive capacity of a beche-de-mer stock. Calculating minimum harvestable length based on this level of conservation requires knowledge of target species' biology, such as sex ratio and size class-specific proportion of

reproductive females. However, this information is currently unavailable for Kosrae stocks. Still, given the urgency of implementing a management plan and given what *is* known about the relationship between holothuroid length and the unavailable parameters (Amesbury 1996), mean length is probably a reasonable and conservative first estimate until such data can be gathered.

Calculating catch per unit effort

We will estimate catch per unit effort (CPUE) for each abundant species at a site during timed swims by three observers. These swims ranged from 5 minutes for very abundant species to 200 minutes for less common varieties. CPUE was then calculated for a given species at an island level ("pooled CPUE") by summing over site abundances *n* of all observers and dividing this by the sum of survey times *t* for all sites and all observers:

$$pooled \quad CPUE = \frac{\sum n_i}{\sum t_i}$$

We also calculated for each species the mean site CPUE over all observers and number of sites *k* at which the species occurred:

$$mean \quad CPUE = \frac{1}{k}\sum \frac{n_i}{t_i}$$

Biodiversity inventory

Divers also recorded all species of echinoderms that they observed at each site to a maximum of 25 m in depth. Collected specimens, or representatives thereof, from nearly all species were photographed *in situ*. One or two voucher specimens of each species were collected, photographed against a black

background and preserved in 95% ethanol or 70% isopropanol. Before preservation, holothuroids were first relaxed in seawater laced with chlorobutanol and chilled to near freezing. No special methods were used to assess infaunal species; divers fanned sediment to uncover such forms or combed the sediment's surface for the tests of burrowing echinoids. Divers looked through rubble and in crevices to find cryptic forms. Night snorkels and dives were used extensively as most coral-reef invertebrates, including echinoderms, are nocturnally active and exposed.

RESULTS

In a total of 14 days of surveying, 21 sites were visited around the island. In the first subsection below, *Stock survey*, we outline the species composition and ecology of commercially valuable species. In the second subsection, *Catch per unit effort*, we calculate catch per unit effort for abundant species. In the third subsection, *Minimum harvestable lengths*, we calculate minimum harvestable lengths for abundant species. In the fourth and final subsection, *Biodiversity inventory*, we report on the species composition and ecology of other holothuroids and echinoderms.

Stock survey

Several commercially valuable species of holothuroids occurred in Kosrae's waters. The most valuable species seen in high abundance were *Holothuria* (*Halodeima*) *atra* (trade name: lolly fish), *Stichopus chloronotus* (green fish) and *Actinopyga mauritiana* (surf red fish). All of these occurred on the reef flats around the island.

Holothuria (*Microthele*) *whitmaei*, the black teat fish occurred much less frequently (approximately six animals were observed during the entire survey) on mid- to outer reef flats islandwide. In other parts of Micronesia, this species also is found on the forereef slope to a maximum depth of about 23 m. In older literature, this species goes by the name of *H.* (*M.*) *nobilis*, a name now reserved for a closely related species from the western Indian Ocean.

The sand fish (*Holothuria* (*Metriatyla*) *scabra*) (Figure 2A) was found in Lelu and Walung in seagrass beds adjacent to mangroves The prickly red fish was uncommon. The prickly red fish was uncommon or absent at most sites.

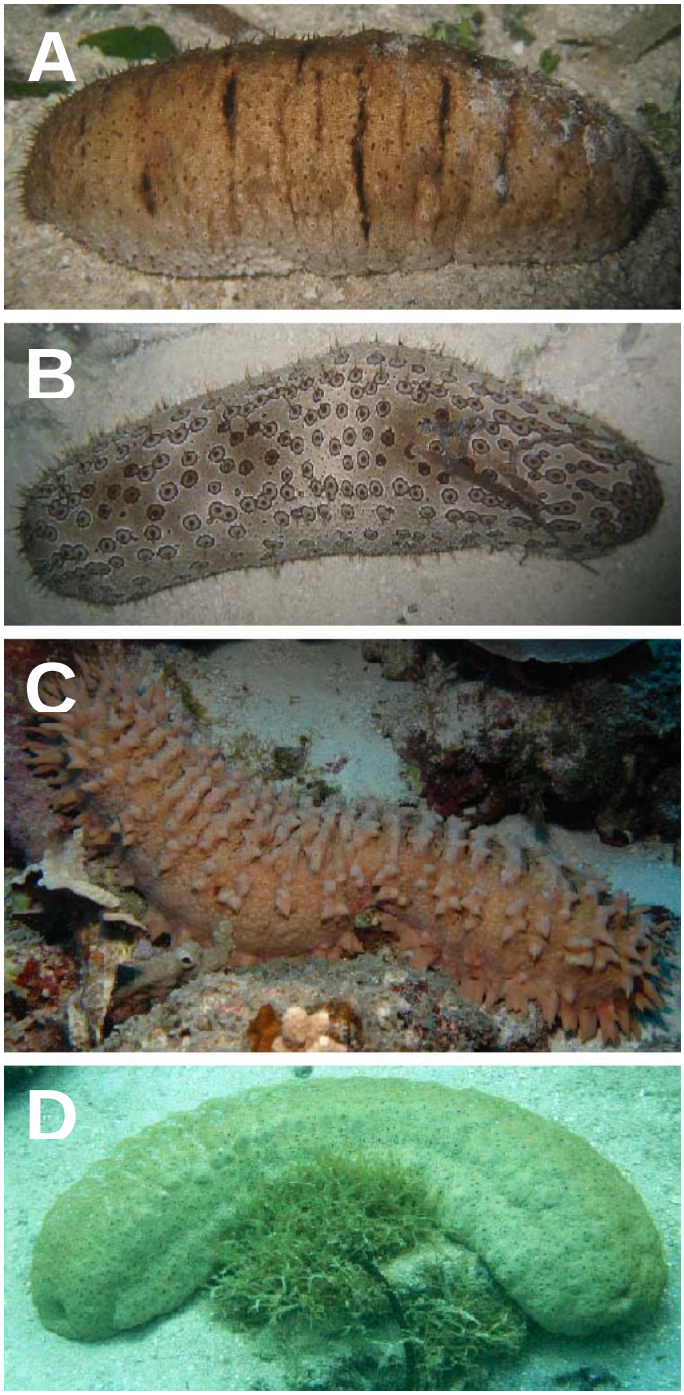

Figure 2. Some commercially valuable species of holothuroids found on Kosrae. A) *Holothuria (Metriatyla) scabra.* B) *Bohadschia argus*. C) *Thelenota ananas*. D) *Stichopus hermannii*

Animals were usually quite large and were usually found on sand bottoms, though individuals were still occasionally seen on forereef slopes on rubble or amongst corals.

Other commercial species, however, occurred at low densities. These included *Bohadschia argus* (spotted fish) (Figure 2B) and *Bohadschia bivittata* (sand fish). Prickly redfish (*Thelenota ananas*) (Figure 2C) was also quite rare, occurring on the outer reef slops. *Stichopus hermannii* (curry fish) (Figure 2D) was very rare, but were among the largest specimens ever seen by the authors (to 70 cm in length).

In sum, Kosrae appears to have several commercially important species of holothuroids that could be harvested in large numbers. How much of these resources can be sustainably harvested is, however, a separate question and will be addressed later in this report under the

Table 1. Catch per unit effort (CPUE) of commercially valuable species of holothuroids on Kosrae. *n* = number of sites with the species; Pooled = CPUE based on pooling all sites for a species; Mean = mean site CPUE; Min = minimum site CPUE; Max = maximum site CPUE.

Species	*n*	Pooled	Mean	Min	Max
Actinopyga echinites	1	0.6	0.6	0.6	0.6
Actinopyga mauritiana	3	3.5	4.3	3.3	6.0
Bohadschia argus	8	9.1	8.4	0.6	27.2
Bohadschia bivittata	2	1.2	1.2	0.6	1.8
Bohadschia marmorata	1	1.8	1.8	1.8	1.8
Bohadschia vitiensis	1	1.2	1.2	1.2	1.2
Holothuria atra	6	42.9	123.8	6.0	270.0
Holothuria edulis	1	5.4	5.4	5.4	5.4
Holothuria scabra	2	1.0	1.3	0.3	2.4
Holothuria whitmaei	4	0.7	0.8	0.3	1.2
Pearsonothuria graeffei	5	7.3	7.3	1.2	21.6
Stichopus chloronotus	6	18.1	17.8	2.4	51.0
Stichopus horrens	4	1.4	1.8	0.3	4.8
Thelenota ananas	5	2.2	2.2	0.6	4.8

section *Recommendations*.

Catch per unit effort

The pooled CPUE values in Table 1 estimate island-wide CPUE for the species. While this was calculated using only sites at which a given species occurred, the values are probably underestimates, since we sampled haphazardly, while fishers will target areas of highest abundance of a species. The mean CPUE is

an average catch per unit effort calculated over sites at which a given species occurred. The minimum and maximum site CPUE are often quite different, indicating wide variability in abundances of a species between sites.

Species in Table 1 found at only a few of the 21 sites surveyed, probably indicate species with more patchy distributions around Kosrae (e.g., *Actinopyga echinites* and *Holothuria* (*Halodeima*) *edulis*). Conversely, species such as *Bohadschia argus*, *Holothuria* (*Halodeima*) *atra* and *Stichopus chloronotus* appear to be both locally abundant – as evidenced by relatively high CPUE – and widely distributed around the island's reefs.

Table 2. Mean *in situ* lengths, pooled across sites, of commercially valuable holothuroids. *n* = sample size; C.I. = confidence interval of mean. Lengths in centimeters.

Species	*n*	Mean Length	Lower 95% C.I.	Upper 95% C.I.
Actinopyga echinites	2	21.0	21.0	21.0
Actinopyga mauritiana	18	21.1	20.8	21.4
Bohadschia argus	126	31.4	31.3	31.5
Bohadschia bivittata	4	27.2	26.8	27.6
Bohadschia marmorata	3	16.7	16.5	16.9
Bohadschia vitiensis	2	26.5	26.2	26.8
Holothuria atra	186	14.5	14.4	14.6
Holothuria edulis	9	17.2	17.1	17.3
Holothuria scabra	5	17.6	17.3	17.9
Holothuria whitmaei	9	26.9	26.5	27.3
Pearsonothuria graeffei	61	29.7	29.6	29.8
Stichopus chloronotus	175	21.1	21.	21.2
Stichopus horrens	13	18.3	17.9	18.7
Thelenota ananas	18	42.9	42.2	43.6

Minimum harvestable lengths

Table 2 shows mean *in situ* lengths of commercially valuable species for which at least three individuals, and upwards of 134 individuals, were measured. The upper and lower 95% confidence intervals indicate the range of lengths over which we can be most confident the true mean length of the entire population of a species occurs.

Figure 3. Some undescribed species of holothuroids found on Kosrae. A) *Holothuria (Thymiosycia)* sp. B) *Bohadschia* sp.

Biodiversity inventory

A total of 75 provisional taxonomic units attributable to species have now been identified from Kosrae's waters: 40 holothuroids, 9 echinoids (sea urchins), 11 asteroids (sea stars), 11 ophiuroids (brittle stars) and 4 crinoids (sea lilies). (Appendix 1). The high number of holothuroids is probably due to an outsized collection effort for these species on our part, rather than a true representation of their proportional richness in the island's echinoderm fauna.

At least four (10%) of the holothuroids are in all probability new to science and formally undescribed. Several were forms usually ascribed to *Holothuria* (*Thymiosycia*) *impatiens*, including one seen for the first time in Kosrae, a large nocturnal tiger-striped species from the outer reef slope (Figure 3A). A second new species, a *Bohadschia* sp. (Figure 3B), was seen in Okat channel, and has also been collected in the Marshall Islands. Another specimen, an asteroid, *Fromia* sp., may also be new.

Addendum: The most recent data, based on nucleotide sequence data generated by one of us (S. W. Kim) suggests that the true number of holothuroid species is somewhat less than listed here. For example, it appears that B*ohadschia bivittata* is genetically identical to, and hence, merely a colour variant of, *B*. *vitiensis*, whose name has taxonomic priority.

DISCUSSION

Prospects for a Sustainable Beche-de-mer Fishery

Kosrae has an abundance of commercially valuable species of holothuroids. We observed populations of some desirable commercial species, occurring at all of the sites we visited around the island. While most of these species are not the most valuable varieties, they, nevertheless, constitute an important and valuable resource for the island.

Conversations with island officials have made it clear that Kosrae is currently being targeted by at least one foreign buyer of beche-de-mer. Local fishers will likely be paid for fresh, unprocessed holothuroids by a Kosrae-based intermediary, who processes the animals into the dried product, which is then sold to the foreign buyer, who ship the beche-de-mer to Asian markets.

Kosrae is just one of many areas that are being heavily targeted by the beche-de-mer industry, whose ships now ply tropical and temperate waters worldwide. The increasing demand for beche-de-mer (and other products, such as shark fin and live reef fish) is fueled in large part by the rapidly expanding cash economies in Asia. Global trade in beche-de-mer is a multimillion dollar industry and profits are high enough, and the industry largely unregulated, that the practice of a "boom and bust" fishery has become commonplace. Quality product (e.g., white teat fish) in Hong Kong markets can retail for over US$130 per kilogram (2.2 lbs). Exporters *preferentially* move into countries where regulation is non-existent and offer low prices for a resource that is easily harvested and is often not being used otherwise. Because of the cost of, and lag in developing, legislating and implementing a management plan, as well as the difficulty of enforcement and

education, the local fishery often collapses before the management plan, if one is put in place at all, can take effect. Exporters know this and exploit this.

Foreign buyers are fully aware that regulations take time to implement and thus, they specifically target small, often young, cash-strapped nations, because there, profits are highest. Buyers often work ”under the radar” of the government by enlisting local intermediaries who encourage collecting and transit of product for export. Foreign buyers often speak in terms of sustainability, such as performing a “demonstration fishery” or an “experimental fishery;” they also speak of the viability of “reseeding,” “aquaculture,” etc. to create an impression that this is the beginning of a long-term relationship. However, and most tellingly, they make *no* commitment, *no* monetary investment to such endeavors, and *no* data are ever methodically collected during the “experiments,” much less analysed or made available in published form, or otherwise, to stakeholders. Alas, the goal of foreign exporters is always the same: obtain as much high-quality product in as short a time as possible and absent any consideration of the sustainability of the fishery, and then move on to the next naive fishery. The list of countries lured into this boom-and-bust practice is both long and growing: Fiji, Solomon Islands, Cook Islands, Galapagos Islands, Egypt…. Given this sad history of repeated over-exploitation, the prospects for Kosrae’s beche-de-mer fishery at first glance seem grim indeed.

Still, despite the generally cheerless prospects for beche-de-mer fisheries worldwide, there are solid reasons for hope with Kosrae. First, there *are* indeed examples of sustainable, long-term fisheries involving beche-de-mer, including those in California (USA), Newfoundland (Canada), Queensland (Australia) and elsewhere. Moreover, Kosrae brings to the table, several strengths, including a strong leadership that values marine resources, plus the public nature of the reef

which permits rapid implementation of legislation aimed at conservation and management.

It is not surprising therefore that in response to the accelerating pace of trade in beche-de-mer and its importance to the local economy, the Kosrae State legislature has implemented a moratorium until the implementation of a management strategy, so as to ensure the long-term success of the fishery. This is a commendable measure and an initial step in avoiding the fate of fisheries in numerous other Pacific-island nations. In the section *Recommendations* that follows, we submit our preliminary suggestions to begin managing Kosrae's beche-de-mer.

For further recommendations on the issue, we highly recommend the detailed report from a workshop that brought together considerable Micronesian-based expertise in the form of fisheries scientists, economists and governmental marine-resource officers: *Suggestions for the Management of Sea Cucumber Resources in Micronesia* (Richmond 1996). This report makes numerous helpful recommendations concerning the management of beche-de-mer fisheries in Micronesia. It has sections covering the biology of holothuroids as they relate to fisheries, management strategies, economic analyses and recommendations for a Micronesian-wide plan to develop beche-de-mer fisheries. Another font of advice and information on beche de mer is available at the website of the South Pacific Commission, http://www.spc.int. Here, on their Coastal Fisheries pages, is a wealth of contact information with fisheries scientists and publications about the latest information on beche de mer, including the long-running publication, *The Beche-De-Mer Bulletin*.

Kosrae's Diverse Echinoderm Fauna

Kosrae now has 75 species of echinoderms recorded from its waters, including 40 species of holothuroids. These counts are likely large underestimates. Yet, the most interesting results from the survey were the new species discovered, all of them holothuroids. At least four species encountered appear to be unknown to science. None appear to be restricted to Kosrae. While uncommon enough to have long avoided formal taxonomic treatment, these species have nevertheless been observed at other localities in the tropical western Pacific by us and others (Kerr et al. 2006, 2007; G. Paulay, personal communication). Other species seen, while known to science, appeared to be unusual morphs seldom or not seen elsewhere in the Indo-Pacific. For example, *Bohadschia argus* usually possesses a light tan or grey to black ground colour. In Kosrae, it was occasionally completely white or black. Several other species of echinoderms also exhibited unusual colour variations.

In sum, Kosrae's biodiversity is both rich and under-explored. The present survey is one of the most complete marine surveys of the island's reefs and indicates that the Kosraean marine fauna is unique and of considerable scientific merit. Surveys of other groups of marine organisms on Kosrae will undoubtedly reveal a comparable number of interesting discoveries, many of them species new to science.

RECOMMENDATIONS

We make some initial recommendations for starting a beche-de-mer management plan on Kosrae. The following approach constitutes only one of several possible starting points.

Institute a moratorium on fishing until a management plan is in place. We understand that a bill has been passed to this effect by the legislature. Note that a moratorium of fixed period is more likely to be violated towards the end of its duration, as poachers and buyers may stockpile product in anticipation of the reinstatement of harvesting. Enforcement at such time should be especially vigilant.

Conduct an inventory of the island's commercially valuable species. We have performed a *preliminary* inventory and have taught methods for continuing the surveys to Marine Resources personnel. An inventory of unharvested (in fisheries parlance, "virgin") stocks provides baseline data to assess the status of the fishery and to estimate the minimum harvestable length (see below). We suggest a quick method for the initial inventory: record the lengths of all commercially exploitable species in timed swims of about an hour per person. This provides two valuable pieces of information: 1) population data on animal size used for calculating minimum harvestable length and 2) an estimate of an important quantity in fisheries management, the catch per unit effort, i.e., how much effort must be expended to harvest a given amount of beche de mer. While a centrally conducted inventory by the government may be desirable, it may also be preferable to ensure that each village performs their own inventory.

Institute island-wide minimum harvestable lengths for each species. Using minimum size is only of one many options for regulating harvesting (See

Amesbury 1996 for other techniques). Minimum length, though, is the simplest measure to implement in the absence of more detailed information on biology and is also the simplest to enforce. The minimum harvestable size of a stock can be roughly calculated for most holothuroids as the average length of a species *before* harvesting has begun. This ensures that close to 50% of the reproductive capacity (50% of all eggs produced) is preserved. For a virgin stock, one not having previously experienced harvesting, this approach to management quickly results in a "fish down," an initial period of large catches of large animals. After this period, catch per unit effort drops considerably as fishers must wait for smaller animals to grow to harvestable size.

Institute MPAs or temporary closures to increase stock size and value. MPAs (marine protected areas) are an additional method by which to preserve the reproductive capacity of a stock. Additionally, "spill over" of animals to areas outside the MPA allows more and larger animals to be harvested. Regulating harvesting by instituting a minimum harvestable size rapidly removes the largest and most valuable stock from the reefs. However, the value of beche de mer rapidly plummets with decreasing product size. Hence, to more quickly grow out the remaining animals to the most valuable lengths, may require seasonal or rotating closures of areas to harvesting. The length of closure will depend on trade offs between economic concerns (e.g., maintaining catch per unit effort) and the growth rates of individual species. Closures might, for example, coincide with the onset of spawning to permit stocks to preserve population size. Determining when spawning occurs can be done as suggested in Richmond, Hopper and Martinez (1996). When closing the reefs to permit regrowth to harvestable size, periodic monitoring of length via timed swims should be performed to learn when reefs can be reopened.

Regulate harvesting and export at the level of local processors. On Kosrae, fishers will likely be selling their catches of fresh animals to a local processor of the final product for sale and shipment to foreign buyers. We recommend mandatory (i.e., legislated) reporting of harvests and percentages of undersized product, with frequent on-site inspections. The intermediaries' dried product can be periodically assessed for lengths and amounts. Lengths will differ from the minimum harvestable lengths mentioned above, because the animal shrinks considerably with processing. Therefore, it will be necessary to know the relationship between minimum harvestable length and its processed length. This in turn requires information for each species on both these lengths for at least 30 or so animals. Then, the relation is determined via the best-fit regression line through the data. We will be happy to assist with these analyses.

Continually assess the effectiveness of the management plan and modify it when necessary. A management plan, especially after it is first implemented, will likely require some fine tuning or, even, a major retool. As more data from monitoring of both stocks and exports collects, it may become clear that modification to harvesting regulations is needed to maintain the goal of the fishery (e.g., continue a reasonable catch per unit effort or level of income). For example, average length is only a very rough guide to estimating 50% reproductive capacity. In fact, average length will usually underestimate 50% reproductive capacity somewhat in most situations. Still, given the biology of holothuroids, it is a reasonable starting point for a beginning fishery. A more refined approach measures gonad weight of females and calculates a minimum length based on reproductive maturity of females. This analysis might suggest that a larger (or smaller) minimum harvestable size is preferable. We also recommend that after a year or two that a fisheries scientist and a fisheries economist (e.g., from the South Pacific Commission or University of Guam) be

invited to learn about Kosrae and its experiences, then have them examine the fisheries at length to suggest other possible refinements.

Uncertainties and potential problems. The above recommendations are made in the absence of much information usually needed to form a fisheries management plan. We, therefore, foresee several issues needing consideration:

1) The main unanswered question is how much money can be sustainably received by a fisher after the initial fish-down of virgin stocks? Will the density and growth rates of the holothuroids permit a continuous harvest, even at some low level, to sustain a trickle of cash into the local economy? These questions concern scale of sustainability and holothuroid life-history traits. The answers should become apparent with increasing data on the status of the fishery, such as interviews with, or surveys of, fishers and their satisfaction with catch size.

2) After fish-down, fishers may become dissatisfied with small catches and insist that management has been a failure. It is important that they understand, perhaps via stakeholder meetings, that ultimately, the amount of harvesting that is sustainable is determined not simply by even the best management, but by the number of fishers and how fast holothuroid reproduce and grow. Alas, tropical holothuroids both reproduce and grow rather slowly. They should be prepared well ahead of time for the possible need for temporary closures to allow stocks to recover.

3) Another important issue is what to do with undersized catch. Because enforcement must occur after processing, the local buyers must incur this risk. This has the beneficial effect them becoming an ally in enforcement at the level of the fisher. Nevertheless, even given these inducements, some portion of the processed product – potentially valuable – will be undersized. Amesbury (1996)

cautions against the temptation to sell undersized product, as it creates a demand for undersized product that will be met by fishers, effectively undermining the management plan.

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Appendix 1. Provisional Checklist of Shallow-water Echinoderms from Kosrae, Eastern Caroline Islands, Micronesia. The subheading "Kerr 1994" indicates the previous survey by one of us (AMK), who found 26 species, noted several varieties of certain species; they are listed here as full species in accordance with present taxonomic thinking. "n. sp." Indicates a provisional new species; other quoted descriptors following the scientific names are informal names used by the authors until a proper name can be designated. Vouchers are housed at the University of Guam Invertebrate Collection (UGI) and the Florida Museum of Natural History (FMNH).

	Survey	
Species	This study	Kerr 1994
HOLOTHUROIDEA		
Actinopyga echinites	X	X
Actinopyga mauritiana	X	X
Actinopyga miliaris	X	X
Afrocucumis africana	X	X
Bohadschia argus	X	X
Bohadschia bivittata	X	X
Bohadschia koellikeri	X	X
Bohadschia marmorata	X	X
Bohadschia tenuissima	X	X
Bohadschia vitiensis	X	X
Bohadschia n. sp.	X	
Chiridota hawaiiensis	X	X
Euapta godeffroyi	X	X
Holothuria (*Acanthotrapezia*) *coluber*	X	X
Holothuria (*Halodeima*) *atra*	X	X
Holothuria (*Halodeima*) *edulis*	X	X
Holothuria (*Lessonothuria*) *lineata*	X	
Holothuria (*Mertensiothuria*) *hilla*	X	X
Holothuria (*Mertensiothuria*) *leucospilota*	X	X
Holothuria (*Metriatyla*) *scabra*	X	X
Holothuria (*Microthele*) *whitmaei*	X	X
Holothuria (*Platyperona*) *difficilis*	X	X
Holothuria (*Staurpora*) *fuscocinerea*	X	X
Holothuria (*Stauropora*) *pervicax*	X	X
Holothuria (*Thymiosycia*) *arenicola*		X

Appendix 1. Continued.

Species	Survey	
	This study	Kerr 2004
HOLOTHUROIDEA		
Holothuria (*Thymiosycia*) *impatiens* “ESU 1”	X	X
Holothuria (*Thymiosycia*) *impatiens* “ESU 2”	X	X
Holothuria (*Thymiosycia*) *impatiens* “big papillae”	X	X
Holothuria (*Thymiosycia*) *impatiens* “tiger stripes”	X	
Holothuria (*Theelothuria*) *turriscelsa*	X	
Labidodemas sp.	X	X
Opheodesoma sp. “olive and white”	X	X
Opheodesoma sp. “red stripes”	X	
Opheodesoma sp. “green in seagrass”	X	
Pearsonothuria graeffei	X	X
Stichopus chloronotus	X	X
Stichopus hermannii	X	
Stichopus horrens	X	X
Synapta maculata	X	X
Thelenota ananas	X	X
ECHINOIDEA		
Clypeaster reticulatus	X	
Diadema setosum	X	
Echinometra sp. A	X	
Echinostrephus aciculatus	X	
Echinoneus sp.	X	
Echinothrix diadema	X	
Eucidaris metularia	X	
Eucidaris n. sp. “orange-spined”	X	
Heterocentrotus aff. *mammilatus*	X	
ASTEROIDEA		
Acanthaster planci	X	
Coriaster granulatus	X	
Culcita novaeguineae	X	
Echinaster callosus	X	
Fromia sp. 1	X	
Fromia sp. 2	X	
Leiaster leachii	X	
Linckia guildingii	X	
Linckia laevigata	X	

Appendix 1. Continued.

Species	Survey	
	This study	Kerr 2004
ASTEROIDEA		
Linckia multifora	X	
Mithrodia clavigera	X	
OPHIUROIDEA		
Ophiocoma erinaceus	X	
Ophiocoma scolopendrina	X	
Ophiocoma sp. 1 “brown, black banded arms”	X	
Ophiocoma sp. 2 “big, orange, in coral”	X	
Ophiocoma sp. 3 “red, white banded arms”	X	
Ophiolepus superba	X	
Ophiothrix purpurea	X	
Ophiuroidea sp. 1 “smooth, brown”	X	
Ophiuroidea sp. 2 “small, white”	X	
CRINOIDEA		
Comaster schlegelii	X	
Phanogenia sp.	X	
Mariametridae sp. 1 “banded”	X	
Mariametridae sp. 2 “violet or white”	X	

Appendix 2. Locality data. Numbers in the first column correspond to those in Figure 1.

	Station	Locality	Habitat	Depth range (m)		Latitude	Longitude
1	KOSR-01	Lelu, in front of Nautilus hotel	reef flat, sea grass, reef moat	0	2	5.34222	163.01986
2	KOSR-02	“Shark island”, Kiyuel, Buoy 40	external slope	7	25	5.35618	162.94691
3	KOSR-03	Trochus Sanctuary, Buoy 37	external slope	6	26	5.34349	162.94647
4	KOSR-04	Sites KOSR-02 and 03	external slope	6	26	5.34349	162.94647
5	KOSR-05	Lelu, in front of Nautilus hotel	reef flat, sea grass, reef moat	0	2	5.34222	163.01986
6	KOSR-06	Buoy 36, West side of Kosrae	Fore Reef slope, heavy coral cover, south of Trochus sanctuary and large channel	12	25	5.33939	162.94311
7	KOSR-07	Okat Channel	sand, scattered rubble, rocks limiting the harbour	0	4	5.35792	162.96439
8	KOSR-08	Okat Channel	intertidal sand, subtidal rocks north of the runway	0	1	5.36173	162.96682
9	KOSR-09	Sroa, Buoy 29	fore reef slope	10	22	5.29649	162.89810
10	KOSR-10	Pac, Buoy 24	night dive, fore reef slope	0	21	5.27471	162.91014
11	KOSR-11	Tafunsak	wide reef flat, sea grass, scattered live corals, rubble on sand	0	1	5.36916	163.01382
12	KOSR-12	Lelu, North Lelu Island	mid to outer reef flat, sea grass, rubble on sand, scattered live corals	0	1	5.33405	163.02907
13	KOSR-13	Lelu, 100m south of KOSR-01	sea grass, scattered coral	0	1	5.34149	163.01992
14	KOSR-14	Okat, Kiwucl, Shark Island, Buoy 40	fore reef slope	6	28	5.35618	162.94961
15	KOSR-15	Okat Channel, South of airport bridge	sand, scattered coral, rubble to moderate coral cover on side of channel	2	4	5.35602	162.96082
16	KOSR-16	Lelu, in front of Nautilus hotel	intertidal sand, between mangrove trees	0	0	5.34222	163.01986
17	KOSR-17	Tafunsak	wide reef flat, sea grass, scattered live corals, rubble on sand	0	1	5.36916	163.01382
18	KOSR-18	Utwe, Inbusbusah, buoy 15	fore reef slope	6	23	5.26275	162.98366
19	KOSR-19	Utwe, Pinglap, buoy 15	fore reef slope	6	26	5.25945	162.98638
20	KOSR-20	Lelu Channel, South Lelu Island		2	10	5.33002	163.02465
21	KOSR-21	Walung	Reef flat, sea grass, scattered corals, reef crest (rocks), blue hole	0	5	5.30883	162.91607

Appendix 3: Authors' contact information

Alexander M. Kerr
Assistant Professor of Invertebrate Zoology
Marine Laboratory
University of Guam
Mangilao GU 96923 USA

Sun Wook Kim
Graduate Research Assistant
Marine Laboratory
University of Guam
Mangilao GU 96923 USA

Francois Michonneau
Graduate Research Assistant
Florida Museum of Natural History
278 Dickinson Hall
Museum Road & Newell Drive
Gainesville, FL 32611 USA