

Abstracts & new publications...

Sea cucumbers fisheries: a manager's toolbox

Friedman K., Purcell S., Bell J. and Hair C. 2008. Sea cucumber fisheries: a manager's toolbox. ACIAR Monograph No. 135. Australian Centre for International Agricultural Research, Canberra. 32 p.

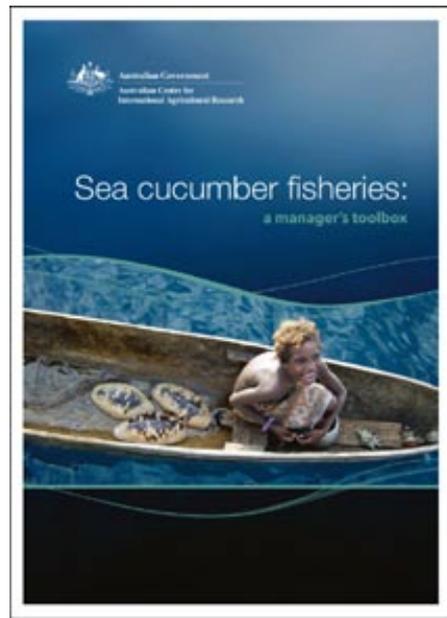
The Australian Centre for International Agricultural Research (ACIAR) is pleased to announce the publication of "Sea cucumber fisheries: a manager's toolbox".

Sea cucumber fisheries are an important source of cash income to isolated coastal communities throughout the Pacific islands region.

This valuable reference tool for managers and fishers provides indicators for assessing the health of sea cucumber fisheries, "best practice" management, and the measures needed to rebuild severely depleted stocks.

Copies will be sent free to key Pacific island fisheries organisations. Visit ACIAR's website to order hard copies online (AUD 9.00 incl. GST). Free electronic download will also be possible from ACIAR's website in late November.

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Abstracts from the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, USA (July 2008), communicated by Dr D. Taddei

New insights into the biodiversity and evolution of aspidochirotid holothurians

François Michonneau, Kris Netchy, John Starmer, Alexander Kerr, Gustav Paulay

Understanding and management of coral reefs depend fundamentally on our ability to distinguish and identify species, in conjunction with knowledge on their origin, distribution and biological characteristics. Yet available information on reef biota remains often inadequate and difficult to access. Aspidochirotid sea cucumbers are a case in point: they include the largest and most conspicuous motile invertebrates on reefs, and are often severely overfished because of their economical value. Identification of some harvested species, even though common, is problematic. We are undertaking a revision of these organisms. Here we

present results from a molecular phylogeny on 200+ taxa, based on 2 mitochondrial gene regions. Results provide insight into macroevolutionary transitions, diversification, and species limits. Holothurians show substantial niche conservatism in latitudinal distribution, depth range, and feeding mode. Heavy reliance on ossicles has led to a confused taxonomy: in some groups ossicles evolve rapidly, possibly in response to variation in carbonate saturation levels, in others they are conserved and mask substantial cryptic diversity. The latter is exemplified by the circumtropical “species” *Holothuria impatiens*. This species complex revealed to consist of at least a dozen reciprocally monophyletic, well-defined, evolutionary significant units (ESUs). Each major tropical region has at least one endemic ESU, the East Pacific and Indo-West Pacific (IWP) host multiple taxa. The latter include peripheral, archipelagic endemics as well as ESUs that range across the entire IWP. Broad overlap in the range of some in combination with recent divergence indicate the rapid evolution of reproductive isolation barriers among these ESUs. Morphological distinctiveness of ESUs vary: some show differences in ossicle morphology, others in live coloration, yet others show no morphological differences that we have been able to discern to date. These results are leading to a better understanding of the varied diversity and diversification mechanisms of reef organisms.

Natural feeding of coral reef holothurian, *Holothuria atra* on microalgae and meiofauna from seagrass beds in Chuuk, FSM

Do-Hyung Kang, Md Abu Affan, Hyun Soo Rho, Sang-Gyu Paik, Heung-Sik Park

The coral reef holothurian, *Holothuria atra* (Jäger, 1833) has an important role in nutrient recycling as a sediment-feeder in coral reef ecosystems. This recycling of nutrients contributes to the high productivity in coral reefs. Limited information is available on the main food sources of *H. atra*, despite their importance on the reefs. This study investigates the food items (i.e. microalgae and meiofauna) consumed by the sediment feeding holothurian, *H. atra*. Sediment samples in front of the mouth, faeces at the posterior and the intestines of the sea cucumbers were taken from each individual. The different sediment samples were fixed in 10% formalin for later qualitative and quantitative analysis of microalgae and meiofauna. Taxonomical determination of microalgae was performed with an inverted microscope. Extraction of the meiofauna was performed using Ludox HS 40 and the species were identified to the class level. Total number of microalgae and meiofauna was identified to 25 species and 10 classes in three different samples, respectively. Microalgae and meiofauna in before feeding sediment were recorded 349 ind ml⁻¹ and 12.2 ind ml⁻¹ with the major groups of Bacillariophyceae and Polychaeta, respectively. After feeding, the microalgae and meiofauna were ingested up to 85.6% and 79.1% by the holothurians. In the intestine contents, the abundance of Bacillariophyceae without chlorophyll was higher than other groups while the abundance of Polychaeta was lower than other groups. This data demonstrated that Bacillariophyceae and Polychaeta were main ingested food items of *H. atra*.

The effects of temperature and light on the gametogenesis and spawning of four sea urchin and five sea cucumber species on coral reefs in Kenya And La Reunion

Nyawira Muthiga, Chantal Conand, Joan Kawaka, Sophie Kohler

This paper reviews studies of the reproductive cycles of 4 species of sea urchins (*Echinometra mathaei*, *Diadema savignyi*, *D. setosum*, *Tripneustes gratilla*) and 5 species of sea cucumbers (*Actinopyga echinites*, *Holothuria atra*, *H. leucospilota*, *H. scabra* and *Stichopus chloronatus*). Measurements of gonad index and macro and microscopic observations of gonads were used to evaluate changes during gametogenesis in individuals collected on Kenyan and Reunion reefs. The effects of temperature, light and lunar period were also assessed. *Echinometra mathaei*, *H. arenacava*, *H. leucospilota* in Kenya and *H. atra* in Reunion showed an annual pattern while *A. echinites*, *H. leucospilota* and *S. chloronatus* in Reunion and *H. scabra* in Kenya showed a biannual pattern of reproduction. A particularly pronounced seasonal pattern occurred in *E. mathaei*, *H. arenacava* and *H. leucospilota* on Kenyan reefs where gametogenesis started in July when temperatures and light were at their lowest and spawning peaked between March-April just after peak levels of temperature and light. These species showed higher correlations between light and gonad index than between temperature and gonad index indicating that light had a stronger influence than temperature on the onset of gametogenesis on these species on the Kenyan coast. In the species without pronounced annual reproductive patterns, gonad indices were high during one (*D. setosum*, *D. savignyi*, *T. gratilla* in Kenya) or two (*A. echinites*, *H. leucospilota* and *S. chloronatus* in Reunion and *H. scabra* in Kenya) periods of 1–2 and up to 6 months but the reproductive season often coincided with periods of high temperature and light. Only three of the sea urchin species (*D. savignyi*, *D. setosum* and *T. gratilla*) showed lunar periodicity.

Cryptic diversity of sea cucumbers: the nocturnal monsters, *Bohadschia* (Holothuroidea: Holothuriidae)

Sun Kim, Alexander Kerr, Gustav Paulay

Sea cucumbers are among the most poorly studied macrobiota on coral reefs. For example, the genus *Bohadschia* (Holothuroidea: Holothuriidae) is often considered one of the most taxonomically controversial groups. In this study, we investigated the systematics of this group using field and molecular methods. Initial findings include that the morphologically and ecologically distinct *B. argus* is derived within the taxonomically muddled *marmorata*-complex. Also, a clade, *B. bivittata* in part, has tiny lines over its dorsum, a character that was not previously considered taxonomically important. In addition, several species, including *B. koellikeri* appear to be hybrids. Finally, we have a lot more to learn about their systematics on reefs worldwide, as we are discovering many new *Bohadschia* species.

Multiple ecological radiations of sea cucumbers onto coral reefs

Alexander Kerr, Ronald Clouse, Mark O'Loughlin, Tim O'hara, Daniel Janies

Aspidochirotida is a large order of sea cucumbers (ca. 25% of extant diversity) consisting of three families: Synallactidae, Stichopodidae and Holothuriidae. Most members are either found on coral reefs or at great depth. We present a phylogeny of 45 species of aspidochirote holothuroids (13% of ordinal-level diversity) based on PCR-amplified partial 16S, 12S, 28S, 18S and H3 gene sequences. Estimated maximum likelihood and maximum parsimony topologies, the latter estimated via POY direct optimisations, indicated that Synallactidae is polyphyletic and renders Stichopodidae paraphyletic. This jumble suggests that members of the former family experienced at least two parallel losses of planktotrophic larvae and complicates interpretations of the bathymetric diversification within the aspidochirotes. The third family, Holothuriidae, appears monophyletic and consists of two large basal subclades. Surprisingly, several previously unconsidered gross anatomical and ecological characters define these groups. The first subclade, "Holothuriinae," is primarily of cylindrical, diurnally cryptic to burrowing forms, while the second subclade "Bohadschiinae," consists mostly of large, diurnal and epibenthic species with flattened ventrums. Further, bohadschiines often release a fluorescent green exudate when first placed in alcohol. These obvious characters permit straightforward diagnosis of two large clades in a family with a tumultuous nomenclatural history.

Rapid speciation, allopatric differentiation, and simple morphology confound true diversity of some of the largest mobile reef invertebrates (*Actinopyga*, Holothuroidea, Echinodermata) [poster]

Kris Netchy, Gustav Paulay, Alexander M. Kerr

As Asian economies grow, so too does the demand for beche-de-mer. In this multimillion-dollar industry, large holothuroids (sea cucumbers) are harvested and sold as food in Asian markets, and overharvesting is an imminent threat throughout the tropics. Holothuroids are among the most poorly known macrobiota on coral reefs, and their systematics is in a poor state worldwide, hampering research and resource management. The systematics of sea cucumbers in the genus *Actinopyga* has been especially neglected. This is primarily because they are among the most morphologically simple and conserved animals, making species differentiation difficult. In this study, two mitochondrial genes, one nuclear gene, and several morphological characters were examined in order to systematically characterize the *Actinopyga*. The data revealed exceptionally fast rates of evolution, clearly structured populations in wide-ranging species, and several examples of cryptic diversity. Understanding the species-level relationships and noting higher levels of diversity than previously thought will allow for better management of beche-de-mer fisheries.

Abstracts from the “Fifth North American Echinoderm Conference, Florida Institute of Technology, Melbourne, Florida, USA, 20–25 July 2008” communicated by A. Kerr

Sea-cucumbers (Holothuroidea: Echinodermata) in western literature from antiquity to Linnæus [talk]

Alexander M. Kerr

The starting point of modern zoological nomenclature is ostensibly the tenth edition of Linnæus' *Systema Naturæ* published in 1758. However, terms likely referable to our totem beasts, the holothuroids, occur sporadically in Western literature as far back as Classical times. In this presentation, I trace holothuroid nomina from a dubious first mention circa 450 BC by the comic poet Epicharmus to the lively series of emendations in disposition within the twelve editions of *Systema* that included as congeners hydrozoans, tunicates and a priapulid worm. The etymology of the term holothuroid itself is likewise uncertain. Indeed, what Aristotle referred to as was doubtless not a sea cucumber at all, but the name, nevertheless, came to designate the class, probably via a mis-ascription in 1554 by Rondelet in his well illustrated *Libri de piscibus marinis*. Nevertheless, the name *Holothuria*, and thus Holothuroidea, was not certain until the ICZN stepped in and finally settled the long-running row over its proper ascription in 1924.

The Holothurian PEET Project and the Aspidochirotid Working Group: Integrative taxonomy on a large scale.

C. Campbell, M. Honey, L. Kenyon, A. M. Kerr, S. Kim, C. Massin, S. McPherson, K. Mezali, F. Michonneau, K. Netchy, M. O'Loughlin, G. Paulay, D. Pawson, F. Rowe, Y. Samyn, S. Smiley, F. Solis-Marin, J. Starmer, A. Thandar, D. VandenSpiegel, T. Werner

We are undertaking a major revision of holothurians, focused on the Aspidochirotida, with support from the NSF PEET program, additional funding from our institutions, governments, and other sources. The project includes reviews of nomina, literature, type specimens, field surveys, DNA sequencing, and revisionary taxonomy. For nomina we are upgrading and databasing Smiley & Pawson's (1990's) manuscript on holothurian names. This is resulting in a comprehensive database of the >2500 available holothurian nomina, with relevant information checked, verified, and captured. Scans of original descriptions of aspidochirotid nomina are being posted on the PEET-cuke web site (<http://67.98.162.85/marinelab/peetcukes/>), together with ca. 4000 references dealing with holothurians. Major repositories with holothurian type material are being surveyed, aspidochirotid type material identified, and fresh ossicle preparations made from relevant tissues of these. Collections in Hamburg, Berlin, Moscow, Paris, London, and our home institutions have now been studied. Many type specimens once considered lost, especially from Semper's work, have been rediscovered. Field surveys have focused primarily on shallow, tropical waters and to date have resulted in large, new collections from the Comoros, Mascarene, Philippine, Vanuatu, Fiji, Mariana, Caroline, Marshall, Cook, Society, Line, and Hawaiian Islands, Australia, Panama, Mexico, Mediterranean basin, Florida, and Washington. Several new species as well as fresh tissue samples from many species were obtained on these trips. DNA has been extracted from >1600 specimens and sequenced from >1100 to date, representing >350 species, focused on aspidochirotids, but covering other available, appropriately-preserved holothurian species. Sequence data, field appearance (including photo-documentation for recently collected material), ossicle complements, and internal anatomy are being integrated to redefine taxa, with many species complex challenges getting sorted out. Student theses and projects are focused on partial to comprehensive revisions of: *Stichopus*, *Actinopyga*, *Bohadschia*, *Holothuria* (*Thymiosycia*), *Holothuria* (*Selenkothuria*), *Holothuria* (*Halo-deima*), and *Synapta*, with other projects in the works.

Other abstracts from various sources

The influence of population density on fission and growth of *Holothuria atra* in natural mesocosms

Jessica Lee, Maria Byrne and Sven Uthicke

Source: Abstract of a paper accepted by the Journal of Experimental Marine Biology and Ecology (2008).

Investigation of the population dynamics, asexual reproduction (fission) and growth of holothuroids has been impeded by the difficulty of tagging individuals. We conducted the first tests on the interactions between population density, fission and growth of holothuroids in experimental populations placed in natural mesocosms (microatolls) at One Tree Reef (OTR), Great Barrier Reef. Similarly sized *Holothuria atra* were translocated to the microatolls in low (LDT) and high (HDT) density treatments. We hypothesised that holothuroids in lower density treatments would have more resources per individual and that this would promote higher frequencies of asexual reproduction and smaller individuals. The seasonal pattern of fission was similar in natural (unmanipulated) and experimental populations, with the maximum number of fission products occurring in winter and spring. The overall density of the LDT (0.19 ind. m⁻²) and HDT (0.59 ind. m⁻²) did not vary over time. This 'steady state' suggested that some fission products died and that asexual reproduction compensated for overall mortality and emigration. There was no difference in sediment chlorophyll pigments between treatments indicating that the different densities of *H. atra* did not affect benthic microalgal biomass. The percentage of fission products was greater in the LDT than the HDT but this difference was not statistically significant, providing some support for the hypothesis that *H. atra* in the LDT exhibit a higher fission rates. At the end of the experiment *H. atra* in LDT were significantly longer and heavier than in HDT. *H. atra* surpassed their initial deployment weight and length after 13 months in the LDT by 115.2% and 45.2% respectively and in the HDT 86.9% and 24.6% respectively, changing from the small to the large phenotype known for this species. This differential growth may be linked to habitat stability and high benthic productivity and demonstrates the phenotypic plasticity of holothuroids and potential to achieve 'Optimum Individual Size' with respect to environmental conditions. Our results will assist in fine tuning conceptual models on asexual reproduction and future experimental studies on the phenomena of fission and plastic growth in holothuroids.

Phenotypic plasticity of gut structure and function during periods of inactivity in *Apostichopus japonicus*

Fei Gaoa, Hongsheng Yang, Qiang Xua, Fangyu Wang, Guangbin Liua and Donovan P. Germanc

Source: Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology Volume 150, Issue 3, July 2008, 255–262.

Apostichopus japonicus is a common sea cucumber that undergoes seasonal inactivity phases and ceases feeding during the summer months. We used this sea cucumber species as a model in which to examine phenotypic plasticity of the digestive tract in response to food deprivation. We measured the body mass, gross gut morphology and digestive enzyme activities of *A. japonicus* before, during, and after the period of inactivity to examine the effects of food deprivation on the gut structure and function of this animal. Individuals were sampled semi-monthly from June to November (10 sampling intervals over 178 days) across temperature changes of more than 18°C. On 5 September, which represented the peak of inactivity and lack of feeding, *A. japonicus* decreased its body mass, gut mass and gut length by 50%, 85%, and 70%, respectively, in comparison to values for these parameters preceding the inactive period. The activities of amylase, cellulase and lipase decreased by 77%, 98%, and 35% respectively, in comparison to mean values for these enzymes in June, whereas pepsin activity increased two-fold during the inactive phase. Alginase and trypsin activities were variable and did not change significantly across the 178-day experiment. With the exception of amylase and cellulase, all body size indices and digestive enzyme activities recovered and even surpassed the mean values preceding the inactive phase during the latter part of the experiment (October–November). Principal Component Analysis (PCA) utilizing the digestive enzyme activity and body size index data divided the physiological state of this cucumber into four phases: an active stage, prophase of inactivity, peak inactivity, and a reversion phase. These phases are all consistent with previously suggested life stages for this species, but our data provide more defined characteristics of each phase. *A. japonicus* clearly exhibits phenotypic plasticity (or life-cycle staging) of the digestive tract during its annual inactive period.

Density and size distribution of the sea cucumber, *Holothuria scabra* (Jaeger, 1935) at six exploited sites in Mahout Bay, Sultanate of Oman

Khalfan M. Al-Rashdi, Michel R. Claereboudt and Saud S. Al-Busaidi

Source: Agricultural and Marine Sciences, 12:43–51 (2007)

A rapid survey of the density and size distribution of recently exploited populations of *Holothuria scabra* in Mahout Bay (Ghubbat Hashish Bay) was carried out at six fishing sites. The results showed that population densities varied between 1,170 and 4,000 ind ha⁻¹ and biomass ranged between 393 and 2903 kg ha⁻¹. The mean size of sea cucumbers and population densities were much lower in populations closer to human settlements, suggestive of overfishing. The sex ratio was estimated to be 1:1 and the size distributions of males and females did not differ significantly. The length-weight relationship for both sexes was calculated as $W (g) = 0.033 \text{ Length (mm)}^2 \cdot 178$.

Additions to the holothuroid fauna of the southern African temperate faunistic provinces, with descriptions of new species.

Ahmed S. Thandar

Source: Zootaxa 1697:1–57 (2008).

This paper is the third and the final one in the series reporting on the numerous lots of unidentified holothuroids received from the South African and Natal Museums. While the first two papers were limited to the fauna of the subtropical east coast, this paper is limited to the fauna of the temperate region of southern Africa, west of the Port St. Johns-East London area, encompassing the warm and cold temperate faunistic provinces, stretching into Namibia. It records and/or describes 23 nominal and four indeterminate, mostly dendrochirotid species. Altogether eight new species and three new records for the region under consideration are included and some new data presented for previously described but poorly known species where these were lacking. The new species are *Sclerothyone unicolumnus*, *Pentacta rowei*, *Cladodactyla brunspicula*, *Panningia trispicula*, *Paracucumaria massini*, *Psolidium pulcherrimum*, *P. pseudopulcherrimum* and *Synallactes samyni* whereas the new records for the region are *Pawsonellus africanus* Thandar and *Pannychia moseleyi* Théel for South Africa and *Pseudoaslia tetracentriophora* Hedding for Namibia.

A new dendrochirotid sea cucumber from the west coast of South Africa (Echinodermata: Holothuroidea: Cucumariidae)

Mageshnee Natasen Moodley

Source: African Zoology (2008), 43(1):61–65

Five specimens of a small cucumariid holothuroid collected between 18 and 32 m, from off St. Helena Bay on the west coast of Western Cape Province, South Africa, are new to science and here described. The presence of une qual tentacles, naked interambulacra, smooth prolonged handle of somebody wall plates and the form of the tentacle and introvert deposits, in combination, sets the new species strongly apart from its congeners.

Reproduction of the sea cucumber *Holothuria leucospilota* in the Western Indian Ocean: biological and ecological aspects

S.M. Gaudron, S.A. Kohler and C. Conand

Source: Invertebrate Reproduction and Development, 51:1 (2008) 19–31 19

Reproduction of *Holothuria leucospilota* was investigated for the first time in the Western Indian Ocean in 2005–2006 in the reef of La Réunion. Two spawning events occurred revealed by gonad index (GI) and histology. Gametogenesis of *H. leucospilota* was divided into five stages of maturity: *resting*, *immature*, *growing*, *maturation* and *post-spawning*. It was synchronous within the population and initiated in July when solar radiation increased. From July to December, the *growing* stage was dominant, followed by a majority of specimen in *maturation* in January. The first spawning event occurred in February whereas the second one

occurred in May. Breeding season of *H. leucospilota* takes place during Austral summer when temperature and tropical rainfall reach their maximal. Between March and June, only 22% of specimens were found with a completely resorbed gonad in *resting* stage. 'Atresia' appeared more frequently in females in an advanced stage of maturity. In male gonad 'atresia' was only observed in the *post-spawning* stage.

Sexual dimorphism was significantly measured in body weight, gonad weight, tubule diameter being all greater in females. An unbalanced sex ratio was skewed (17:191) towards females. Weight at the first maturity was defined for a total weight above 180 g. All of these biological aspects are relevant for the conservation of *H. leucospilota* species in the Western Indian Ocean that is under fishing pressure.

Restoring small-scale fisheries for tropical sea cucumbers

Johann D. Bell, Steven W. Purcell, Warwick J. Nash

Source: Ocean & Coastal Management 51 (2008) 589–593

Overfishing threatens to extinguish local fisheries for valuable tropical sea cucumbers by reducing population densities to the point where reproductive success trails behind natural mortality (known as depensation or the 'Allee effect'). Once this happens, conventional management measures alone, such as closed seasons/areas, size limits and gear restrictions, will usually fail to repair the damage. A different suite of active management interventions must be considered to restore the spawning biomass of severely over-exploited populations. These include: (1) restocking no-take zones with hatchery-reared juveniles; (2) aggregating remnant wild individuals in no-take zones; and (3) development of small enterprises to rear wild-caught sea cucumbers in simple sea pens, or dedicated sublittoral areas, to the size above sexual maturity that optimises earnings. The first intervention is currently limited to a few species of tropical sea cucumbers, whereas the second and third interventions can be applied to many species. The third intervention is particularly attractive – it allows fishers to add value to their catch, reverses the effects of fishing from damaging to improving the potential for replenishment by overcoming the Allee effect, and creates multiple groups of spawners to supply recruits throughout the range of the population(s) supporting a fishery.

Captive breeding and sea ranching of commercially important tropical sea cucumbers in Australia

Dr Daniel Azari Beni Giraspy

Source: Abstract of a paper presented at the "Australasian Aquaculture Conference" held in Brisbane, Australia, 3–6 August 2008

Overfishing of holothurians is affecting sea cucumber population worldwide, and aquaculture and restocking programs are needed to meet the demand and also to bring back the depleted fisheries to sustainable level. The demand for *beche de mer* is significantly increasing in Asia, making the sea cucumbers more vulnerable for exploitation. Among the 1,250 known species of sea cucumbers, about 20 species have commercial value. The sea cucumbers Sandfish (*Holothuria scabra*) and the Golden Sandfish (*H. versicolor*) are considered to be the most valued of the tropical edible species with highest prices on the international export market.

Bluefin Seafoods Pty. Ltd., Hervey Bay, Queensland has received an innovation grant from the Federal Government of Australia to develop and perfect the hatchery technology for mass production of sea cucumbers for restocking programmes. Under this programme, the techniques for the mass production of *H. scabra* (sandfish) and *H. versicolor* (golden sandfish) have been developed and millions of sea cucumber juveniles have been routinely sea ranched during the past few years. The operation includes; Broodstock Collection: sea cucumbers are collected by diving during spring season, when the gonad index is over seven. 2 to 5 ind m⁻² are placed in flow through sea water system with dissolved oxygen over 5.5 mg L⁻¹ and feeding rate between 5 and 7% of body weight. Spawning stimulation and fertilisation: spawning inducement is by thermal shock (temperature raised by 3–5°C). Males spawn first followed by the females. The diameter of the fertilised egg is around 180 µm. Fertilised eggs hatch into auricularia larva within 48 hrs of fertilisation and starts feeding on microalgae Larval rearing and Feeding: larvae are reared in 1000-L fiberglass tanks at a density of 0.5 ml⁻¹. During the larval rearing period the temperature was maintained between 25 and 27°C, salinity ranged between 37.5 and 38 ppt, while pH remained at 8.2. Larval diet consisted of *Rhodomonas salina*, *Chaetoceros calcitrans*, *C. mulleri*, *Isochrysis galbana* and *Pavlova lutheri* in different combinations at different larval stages. Feeding regime depends on the developmental

stage and from early auricularia to late auricularia stage, microalgal density is gradually increased from 15,000 cells ml⁻¹ to 35,000 cells ml⁻¹. Larval development and settlement: the auricularia larvae develop in to doliolaria and pentacula stages before they metamorphose into juveniles. The non-feeding doliolaria larvae are transferred to tanks with settlement cues and the flow-through system is maintained. Early juveniles attach on the settlement substrates on the nursery tanks. The corrugated plates with settlement cues facilitate pentacula attachment and juvenile growth. Nursery phase: the settled juveniles spend three months in the nursery tanks and artificial feeds are used to feed the growing juveniles. 3 to 5 cm size juveniles are ready to sea ranch. Sea ranching: The keys to successful sea ranching are site selection and routine management. Sea cucumber juveniles are sea ranched in sheltered bays with sea grass. The areas with fewer predators such as sea stars and crabs are preferred for successful sea ranching. Mass production of sandfish and golden sandfish are quite feasible with our hatchery technology. This technology can be used for aquaculture production as well as for the restoration of depleted wild populations to allow sustainable fishery. The hatchery technology for other commercially important sea cucumbers is under-way to refine technology for the better settlement and higher survival rates.

Characterization, control and optimization of the processes involved in the postmetamorphic development of the edible holothuroid *Holothuria scabra* (Jaeger, 1833) (Holothuroidea: Echinodermata)

Thierry Lavitra

Source: PhD Abstract – University of Mons-Hainaut – Septembre 2008

Studies on characterization, control and optimization of the processes involved in the postmetamorphic development of the edible sea cucumber *Holothuria scabra* (Jaeger, 1833) were carried out between 2004 and 2008, for one part in Toliara (south-west of Madagascar) and for another part at the University of Mons-Hainaut. Holothuriculture is a mariculture in full expansion. Natural populations of various species of sea cucumbers are in decline due to the ever increasing demand of Asian populations; particularly of China who consider these animals as delicacy food. The present work was performed under the PIC project "Tropical holothuriculture" which aims at putting in place, in Madagascar, the first hatchery and farm of holothuroids in the south-ouest of Indian-Ocean. The researches aimed firstly to determine the effect of food quality and of the rearing density on survival and growth of *H. scabra*. The nutritional activity of *H. scabra* was also analyzed by integrating data on the nycthemeral cycle of individuals and other data regarding the sediments composition, the excrements and the food bowl. This work also aimed to present the problems encountered during the farming period, to characterize their impact on the holothurian production and to propose solutions allowing to avoid them or to limit their impact. It also allowed to identify the methods used in Toliara region for trepang (dried and exported holothurians) processing, particularly for *H. scabra*, to analyze the morphometric parameters linked to the transformation process and to update the information on holothurian commercialization from the collect until their delivery to the exporters.

To optimize survival and growth rates of epibenthic juveniles of *H. scabra*, the experiments suggested the use of brown algae *Sargassum latifolium* (Turner, 1809) as their food and a rearing density of 450 ind. m⁻². When they reach the size of 15 mm (8 weeks), epibenthic juveniles become endobenthic (*i.e.*, they burrow into the muddy sand from sun rise to sun set). They are transferred into pounds covered with sediments collected from the sea grass bed. The rearing density should not exceed 20 ind m⁻². The mixed farming with the fish *Térapon jarbua* (Forskall, 1775) is suggested in order to avoid invasion of isopods parasites (crustaceans) encountered during warm season. When they reach the average weight of 15 g (6 cm long; 6 to 8 weeks), juveniles are placed into enclosures at sea, at a rate of 2 ind m⁻². Before the transfer, strict controls of the sites in the natural environment must be achieved in order to avoid predators. The most redoubtable predators in Toliara region are the crabs *Thalamita crenata* Rüpell, 1830.

H. scabra are detritivores, ingest sediment where they live. They came out of the sediment where they burrow, at the beginning of the afternoon to feed; they burrow again before the sunrise. A *H. scabra* adult ingests on average 101 g of sediment (dry weight) day⁻¹, which is 29% of their fresh weight. They select particles less than 2 cm of diameter, and extract the organic matter where they feed bacteria. The bacteria in sediments and in the excrements highlighted by FISH method (*In Situ* Fluorescent Hybridation) belong to the group of *Cytophaga-Flexibacter-Bacteroides*, of δ -Protéobactéria and of γ -Protéobactéria.

Several processing methods are employed by the fishers in littoral villages in Toliara region. As a general, *H. scabra* are eviscerated, boiled, treated with papaya leaves in order to remove the chalky spicules and sun

dried. In general, whatever their initial sizes, individuals lose 91 % and 52 % of their weight and length respectively after the processing. The actors of the commercial chain are beyond the fishers, the middlemen, the collectors and the exporters. Trepanng of the first category may be sold presently between USD 33 to 50 kg⁻¹ to the exporters.

Impact of removal - A case study on the ecological role of the commercially important sea cucumber *Holothuria scabra* (Echinodermata: Holothuroidea) in Moreton Bay, Australia

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Source: PhD abstract, University of Rostock, 2008

The ecology of holothurians, their ecological role in marine ecosystems, and the potential impacts of their removal (through over-fishing) was the subject of this study. This was investigated by focusing on important aspects of holothurian behavioural dynamics, such as burying and feeding, as well as assessing their impact on important habitat variables such as sediment mixing, and seagrass and algae biomass and productivity.

Certain species of holothurians have been harvested for the human food consumption for centuries. The dry products of the body wall (also called 'bêche-de-mer' or 'trepanng') of these animals are considered as a delicacy to the Asian (particularly Chinese) food industry. Currently, there are more than 20 holothurian species that are commercially used around the world. *Holothuria scabra* is one of those most targeted species due to their thick body wall and large size. Since most commercial species inhabit shallow waters and are easily harvested by hand at low tide, high value species such as *H. scabra* are easily over-exploited. *H. scabra* are already over-exploited or extinct in many locations such as Solomon Islands, some places along the Indian coast and in many places along the South-East Asian coastline.

The main objectives of this study were to: (a) document the difference in the productivity and biomass of seagrass and benthic microalgae (BMA) with and without *H. scabra* by means of *in situ* exclusion cages, (b) quantify the rate and extent of vertical sediment transport associated with feeding and burying of *H. scabra* using luminophores as tracers in aquaria, and (c) investigate the relationship between burying and feeding behaviour and temperature (within a seasonal context) by means of continuous long-term monitoring of *H. scabra* behaviour in mesocosms.

Exclusion experiments were conducted in shallow seagrass habitat to investigate the impact of holothurians on seagrass biomass and productivity. In addition, sediment samples were taken to measure BMA biomass and organic matter (OM). Holothurians appear to be beneficial for seagrass, with significantly higher seagrass productivity (12%, ANOVA, $p = 0.008$) and slightly higher seagrass biomass (18%, ANOVA, $p = 0.348$) under natural holothurian densities compared to exclusion areas. Conversely, the presence of holothurians appeared to reduce BMA biomass and OM, as suggested by higher BMA biomass (ANOVA, $p = 0.089$) and OM content (ANOVA, $p = 0.110$) in exclusion cages. Combining all major response variables in a Principal Component Analysis (PCA) suggested that the exclusion of holothurians caused marginally significant differences in those variables compared to natural densities (MANOVA, $p = 0.074$).

The results of bioturbation experiments demonstrated that *H. scabra* caused mixing of the surface sediment layers during their feeding and burying activities. Instantaneous sediment mixing rates (IMR) of 0.016% d⁻¹ were calculated for the top 2 cm for *H. scabra* at natural densities (0.48 ind m⁻²). Moreover, the holothurians did not influence sediment deeper than 6 cm and their pattern of bioturbation created a relatively smooth sediment surface with the formation of a shallow anoxic layer (3–6 cm). A new mode of bioturbation for these animals is suggested, categorising holothurians as "conveyor diffusors".

Overall findings of the behaviour study showed that differences in burying and feeding behaviour of adult *H. scabra* were strongly related to water temperature, thus resulting in drastic seasonal changes in behaviour. Austral winter (Jun-Aug) was a time of very low activity with most animals being buried for whole or part of the day, feeding only a few hours each day and displaying very little to no searching activity. Austral summer (Nov-Feb) was a time of high activity with short periods of being buried (early morning), frequent feeding and searching (morning, afternoon and late evening) and some spawning activity occurring (late afternoon). The behavioural pattern during shoulder seasons (Mar-May and Sep-Oct) was similar to that observed during summer. The exception was searching activity, which occurred more frequently during the shoulder seasons, due to higher food requirements (e.g. preparation for spawning). Hence, the ecosystem function of holothurians was altered dependent on seasons and needed to be taken into account when establishing an ecological role of those animals within their habitat.

Results of this study demonstrated a potential mechanism by which fisheries for holothurians may impact their surrounding habitats and result in indirect cascading ecological consequences for the animal's ecosystem function. Furthermore, given that seagrass habitat is a known nursery for other important fishery species (e.g. prawns), there is the potential for an impact in one fishery (holothurians) to be linked to another. Over-fishing of holothurians might alter the overall habitat structure in unpredictable ways and could thus have consequences for the ecology of tropical seagrass beds in the long term. Furthermore, findings in this study have implications for population surveys for *H. scabra* when relying mainly on visually counting animals along transects. Surveys should be conducted at consistent diel and seasonal timing if results are to be compared with previous data. Based on burying data presented in this study, it is suggested that the most suitable time to conduct population surveys on *H. scabra* would be during austral summer (Nov.–Feb.) from midday to late afternoon.

Most of the findings in this study were based on individual *H. scabra* and their ecological role as ecosystem engineers. However, one of the most important aspects of this research was the ability to use the acquired results and draw conclusions as to the wider population of *H. scabra* within Moreton Bay. By using models of activity dynamics in combination with sediment transport rates, this study estimated the overall impacts *H. scabra* population had on their associated habitat in Moreton Bay.

The reproductive biology of sandfish *Holothuria scabra*, tigerfish *Bohadschia argus*, and asexual reproduction mode of Warty Selenka's sea cucumber *Stichopus horrens* and prospective management option for sea cucumbers fisheries in Tongan coastal waters

Source: BSc supervised by Dr Mike Barker, University: Otago University, Dunedin, New Zealand (Sep. 2007).

Holothurians (sea cucumbers) are one of the five extent classes of echinoderms which exploited commercially in the Indo-Pacific including Tonga. The rising demand for sea cucumbers in international markets has caused declines in many holothurian populations worldwide. The Tonga government banned commercial fishing of sea cucumbers in late 90s based on stock assessments carried out by the South Pacific Community, and the fishery hasn't been opened since then.

The sandfish *Holothurians scabra* is one of the most valuable sea cucumber species exploited commercially in the Indo-Pacific whereas the tigerfish *Bohadschia argus* had lower commercial value. The Selenka's sea cucumber *Stichopus horrens* is one of the most important subsistence fisheries in Tonga and in other South Pacific Islands. Typically the viscera of the live animal are collected and the sea cucumber is then released back on the reef. Folklore has it that the internal organs are regenerated in a few days.

The objectives of the present study were to determine the reproduction pattern of *H. scabra* and *B. argus* during summer periods in Tongan coastal waters. For *S. horrens* the study was focused on the process of organ regeneration, particularly how long it takes for the internal organs to be replaced.

To study the reproductive biology of the above sea cucumbers species, 20 individuals of *H. scabra* and *B. argus* were collected from November 2005 to April 2006 and the gonad index (GI), gonad tubules sizes, gonad maturity stages (stages 1 to stage 5), were determined and compared with other studies. For *S. horrens*, 4 replicates and 2 controls cages were set up at the most common fishing ground for this species with a back up experiment at the Ministry of Fisheries aquaculture facilities. Animals were cut open and the internal organ (intestine and gonads) removed. Undamaged animals were used as controls (20 animals for each cages).

The GI for *H. scabra* and *B. argus* were not significantly different between sexes ($P = 0.383$ for *H. scabra*, $P = 0.380$ for *B. argus*) but variable across months. The maximum GIs were recorded in December 2005 and February 2006 for *H. scabra* but high indices for *B. argus* also occurred in March 2006. Both species had similar patterns of maturity stages revealed by histological analysis. Mature stages (stage 3) were present in the ovaries throughout the sampling periods for both species. The testes were dominated by pre-spawned stages (stage 4). Oocytes sizes varied between months for both the study species. The tubule length and diameter were significant difference between sexes for both *H. scabra* and *B. argus* ($P = 0.000$).

The body tissue of *S. horrens* only took 2 to 5 days to repair however internal organ were regenerated over 30 days

The overall results for the reproductive biology of *H. scabra* and *B. argus* in Tonga indicated that the spawning activities occur during the summer season, a similar reproductive pattern to that found in New Caledonia

and the Great Barrier Reef (Australia) coastal waters. However, this study does not allow the full reproductive cycle for these species to be determined for Tonga, due to limits of the length of the sampling period that were possible (NZAID regulations on student travel). In *S. horrens* the period taken for regeneration was similar to the length of time found for other sea cucumber species. Also *S. horrens* was found to undergo asexual reproduction.

The management of sea cucumber fisheries in Tonga has been consistently focused on size limits. The future options for managing the sea cucumber fisheries in Tonga are discussed also.

Bio-écologie et exploitation de deux espèces d'holothuries aspidochirotés, *Holothuria notabilis* et *Stichopus horrens* dans la baie de Toliara (Sud-ouest de Madagascar)

Razafimandimby Yacinte

Source: Mémoire de DEA Océanologie, Université de Tuléar, IH-SM (2008).

The study on “the bio-ecology and the exploitation of the sea cucumber species *Holothuria notabilis* and *Stichopus horrens* in Toliara bay” make available the bio-ecological characteristics of these species for which it is the first study at the world scale. The density of the population of *H. notabilis* from the sea grass beds is on average 200 individuals per hectare or 31% of the total sea cucumber density in these environments. It is a small size species. It reaches the first sexual maturity at a total weight of 63 g.

The population of *S. horrens* has a density of 50 individuals per hectare and also accounts for 31% of the sea cucumber density from the reef-flat of the Mareana is let which is lower in sea cucumbers. The weight at first sexual maturity is 254 g. It is a species of average size.

The two studied species are characterized by an annual cycle of reproduction. Globally, the reproductive periods take place during warming of sea water.

The analyses of the exploitation of sea cucumbers in Ankilibe village showed that the annual production is estimated at 5 tons of trepang (dried weight) including 63% of *H. notabilis* and 13% of *S. horrens*. All the categories of villagers take part to the fishery and they even collect some juveniles.

These bio-ecological and socio-economic data could contribute to management measures for rational and durable management of the sea cucumber fishery in the South-west region of Madagascar or even for the whole Island.

Étude de l'évolution de l'exploitation d'holothuries au cours des 10 dernières années (1996–2006) dans la region sud-ouest de Madagascar Zone Nord

Rakotomahefa Solofondraibé

Source: Mémoire de fin d'études MaST/ML. Université de Tuléar, IH-SM. 40 p. + annexes. (2008).

Étude de l'évolution de l'exploitation d'holothuries au cours des 10 dernières années (1996–2006) dans la region sud-ouest de Madagascar Zone Sud

Andriatsimalona Sitrako Jo-Martin

Source: Mémoire de fin d'études MaST/ML. Université de Tuléar, IH-SM. 43 p. + annexes. (2008).
