

Abstracts and new publications...

An overview of the Australian psolid sea cucumbers (Echinodermata: Holothuroidea: Psolidae) with the description of 5 new species

M. Mackenzie and E. Whitfield

Zootaxa 3037: 21–36 (2011)

Four new species of *Psolus* Oken from Australia are described: *Psolus parantarcticus* sp. nov. from Macquarie Island, *Psolus salottii* sp. nov. from South Australia and Macquarie Island, *Psolus steuarti* sp. nov. from Victoria, and *Psolus springthorpei* sp. nov. from Queensland. One new species of *Psolidium* Ludwig from Australia is described: *Psolidium oloughlini* sp. nov. from King Island. All Australian psolid species are included in the overview: *Ceto cuvieria* (Cuvier), *Psolidium berentsae* O'Loughlin and Maric, *P. granuliferum* H.L. Clark, *P. hutchingsae* O'Loughlin and Maric, *P. karenae* O'Loughlin and Maric, *P. laperousazi* O'Loughlin and Maric, *P. marshae* O'Loughlin and Maric, *P. mccallumae* O'Loughlin and Maric, *P. minutum* (H.L. Clark), *P. nigrescens* H.L. Clark, *P. parmatum* (Sluiter), *P. ravum* Hickman, *P. spinuliferum* (H.L. Clark), and *Psolus antarcticus* (Philippi). A key to the Australian species of Psolidae is provided.

Holothuria (Selenkothuria) carere, a new species of sea cucumber (Echinodermata: Holothuroidea) from the Mexican Pacific

M. Honey-Escandón, F.A. Solís-Marín and A. Laguarda-Figueras

Zootaxa 2922: 27–33 (2011)

A new species of sea cucumber of the subgenus *Selenkothuria* is described. *Holothuria (Selenkothuria) carere* was found in the Mexican Pacific, from intertidal to 1 m depth. The absence of ossicles in the body wall, as well as in the dorsal and ventral tube feet make this species unique among the rest of the species of this subgenus. Smooth straight rods with distal perforations and projections are only present in the dorsal and anal papillae, papillae at the base of the tentacles and in the tentacles. This species is clearly distinctive within the subgenus. The shape of the ossicles shows some similarities with *H. (S.) glaberrima*.

Present status of the commercial sea cucumber fishery off the north-west and east coasts of Sri Lanka

D.C.T. Dissanayake and G. Stefansson

Journal of the Marine Biological Association of the United Kingdom. DOI: 10.1017/S0025315411001019

The sea cucumber fishery has been providing an important means of livelihood to the coastal fishing communities in Sri Lanka for centuries. Stock status, level of exploitation and mortality parameters of eleven commercial sea cucumber species were studied off the north-west and the east coasts of Sri Lanka using data collected from an underwater visual census and fishery-dependent surveys carried out in 2008 and 2009. The total abundance of sea cucumbers was higher in the north-west than the east ($P < 0.01$). However, the total abundance of all the species declined between 2008 and 2009. The commercial fishery predominantly relies on two nocturnal species: *Holothuria spinifera* and *Thelenota anax*. *Holothuria spinifera* had the highest contribution (73.2%) to the total landings in the north-west while this was provided by *T. anax* (93%) in the east. Both catch per unit effort and total landings declined in 2009 compared to 2008 having three exceptions (*H. spinifera*, *Holothuria atra* and *Stichopus chloronotus*) in the north-west. Further, the collection of immature individuals, reduced landings of high-value species and temporal shifting of fishing activities were observed in both areas. Two approaches (simple linear regression and random effects models) were used to estimate the natural mortality of sea cucumbers and the estimated values were 0.50 yr^{-1} and 0.45 yr^{-1} , respectively. Apart from the management of local sea cucumber resources, this information is important to update the regional and global sea cucumber statistics as well as for launching regional management

Habitat preference of sea cucumbers: *Holothuria atra* and *Holothuria edulis* in the coastal waters of Sri Lanka

D.C.T. Dissanayake and G. Stefansson

Journal of the Marine Biological Association of the United Kingdom. DOI: 10.1017/S0025315411000051

Despite their economic importance, the ecology of many sea cucumber species is poorly understood and factors influencing their habitat preferences remain largely unexplained. The distribution and habitat preference of two sea cucumber species; *Holothuria atra* and *Holothuria edulis* were studied off the north-west coast of Sri Lanka by underwater visual census in October 2008. The relationships between the density of each species and the habitat variables, such as mean grain size, organic content (% of dry weight), gravel (%), silt–mud (%), and depth, were examined using a generalized additive model. All these variables except silt–mud have significant influence ($P < 0.05$) on the habitat association of *H. atra*. The shallow water (<10 m) seagrass habitat with sediments characterized by 2–3.5% organic content, 15–25% of gravel and coarse sand (0.7–1.2 mm) were the most preferred conditions by *H. atra*. High densities of *H. edulis* were found in the shallow (<10 m) depths of rocky areas with algae and seagrass. Favoured bottom sediment conditions of *H. edulis* were mainly similar to the conditions preferred by *H. atra*, except organic content which did not significantly influence the habitat preference of this species. The preference towards the specific habitat characteristics seems to be associated with their feeding and protection. An understanding of habitat preference would be useful to improve the management of these sea cucumber populations and enable more precise stock assessment.

Potential influence of sea cucumbers on coral reef CaCO₃ budget: a case study at One Tree Reef

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To endure, coral reefs must accumulate CaCO₃ at a rate greater or equal than the sum of mechanically, biologically and chemically mediated erosion rates. We investigated the potential role of holothurians on the CaCO₃ balance of a coral reef. These deposit feeders process carbonate sand and rubble through their digestive tract and dissolve CaCO₃ as part of their digestive process. In aquarium incubations with *Stichopus herrmanni* and *Holothuria leucospilota* total alkalinity increased by 97 ± 36 and 47 ± 18 $\mu\text{mol kg}^{-1}$, respectively. This increase was due to CaCO₃ dissolution, 81 ± 34 and 34 ± 16 $\mu\text{mol kg}^{-1}$ and ammonia secretion, 16 ± 4 and 14 ± 4 $\mu\text{mol kg}^{-1}$, respectively for these species. Surveys conducted at a long term monitoring site of community calcification (DK13) on One Tree Reef indicated that the density of sea cucumbers was ca. 1 individual m⁻². We used these data and data from surveys at Shark Alley to estimate the dissolution of CaCO₃ by the sea cucumbers at both sites. At DK13 the sea cucumber population was estimated to be responsible for nearly 50% of the nighttime CaCO₃ dissolution, while in Shark Alley for most of the night time dissolution. Thus, in a healthy reef, bioeroders dissolution of CaCO₃ sediment appears to be an important component of the natural CaCO₃ turnover and a substantial source of alkalinity as well. This additional alkalinity could partially buffer changes in seawater pH associated with increasing atmospheric CO₂ locally, thus reducing the impact of ocean acidification on coral growth.

Putting into practice an ecosystem approach to managing sea cucumber fisheries

FAO

Source: FAO, Rome. <http://www.fao.org/docrep/013/i1780e/i1780e00.htm>

Artisanal and industrialized fishers from more than 40 countries harvest more than 60 species of sea cucumbers. These low-food-chain resources play important roles in nutrient recycling and sediment health in marine habitats. Owing to ease of capture and vulnerable biological traits, sea cucumbers have been easily overexploited in most countries, sometimes to local extinction. Few sea cucumber fisheries are currently managed sustainably. They differ greatly in the scale of the fishing activities, status of stocks and management capacity. This document summarizes general management principles and a general framework for developing and implementing a management plan. Through a few questions and simple indicators, managers are guided to choose appropriate sets of regulatory measures and management actions for different sea cucumber fisheries. Safeguarding sea cucumber stocks for current and future generations will require an ecosystem approach to fisheries (EAF) that applies precautionary measures with the participation of stakeholders. Success in applying an EAF will require consideration of the reproductive productivity of stocks, ecosystem health and the socio-economic systems that drive exploitation.

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Comparative study of reproductive synchrony at various scales in deep-sea echinoderms

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Deep-sea Research Part I 58(3): 260–272 (2011)

This study examined the influence of temporal and spatial factors on the determination of reproductive cycles in selected deep-water echinoderms. The prevalence of inter-individual synchrony in the gametogenesis of three ubiquitous species, *Phormosoma placenta* (Echinoidea), *Hippasteria phrygiana* (Asteroidea) and *Mesothuria lactea* (Holothuroidea) collected off the coast of Newfoundland and Labrador (eastern Canada), was determined. Analyses revealed diverse degrees of gametogenic asynchrony at the scales examined (within trawls, between trawls over similar or different periods, as well as among depths and locations over the same period). Taken as a whole, samples did not show any annual or seasonal patterns, whereas some sets of samples, taken over a particular time period in the same area and at the same depth, revealed well synchronized maturing and/or spawning periods in *P. placenta* and *H. phrygiana*. This study presents evidence that determination of reproductive cycles in many deep-sea species may be affected by low sampling resolution inherent to most deep-sea studies. More accurate assessments of reproductive patterns and periodicities may require much tighter collection designs as several species are likely to rely on long-term or transient pairing and aggregation to synchronize their breeding activities.

Genetic population structure in a commercial marine invertebrate with long-lived lecithotrophic larvae: *Cucumaria frondosa* (Echinodermata: Holothuroidea)

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Marine Biology 158:859–870 (2011)

The patterns of genetic diversity and connectivity were investigated in *Cucumaria frondosa*, the most abundant sea cucumber in the North Atlantic, to assist in the management and conservation of this ecologically important marine invertebrate, which is the target of an emerging fishery. Mitochondrial DNA COI sequences of 334 *C. frondosa* were obtained and analyzed, mainly from its western North Atlantic range, where the commercial fishery is being developed, with complementary sampling in the mid- and eastern North Atlantic. Analysis of molecular variance showed no significant ($P > 0.05$) differences among subpopulations in the western region suggesting that it constitutes one panmictic population. The same analysis showed low, but significant differences between eastern and western Atlantic populations. Coalescent analyses using isolation with migration models and a Bayesian skyline plot indicated historical divergence and a general increase in population size prior to the last glacial maximum and highly asymmetric gene flow (nearly 100 times lower from west to east) between sea cucumbers from North America and Norway. Results suggest that subpopulations of *C. frondosa* within the western North Atlantic have been highly connected. We propose that aided by the high-connectivity local subpopulations can recover rapidly from natural (i.e., ice ages) or anthropogenic (i.e., overfishing) population declines through recruitment from deep refugia.

Synchronized breeding events in sympatric marine invertebrates: role of behaviour and fine temporal windows in maintaining reproductive isolation.

A. Mercier and J.-F. Hamel

Behavioral Ecology and Sociobiology 64: 1749–1765 (2010). http://www.mun.ca/osc/amerrier/Pages_from_BES_2010.pdf

While breeding synchrony among conspecifics is increasingly well understood with regards to the reproductive success of vertebrate and invertebrate taxa, the occurrence of simultaneous multispecies breeding events remains intriguing. The fairly recent discovery of mass annual spawnings in reef corals has provided a first glimpse at putative strategies of reproductive isolation during such events. However, the mechanisms and advantages of same-day heterospecific breeding are still poorly understood and have not yet been investigated in non-coral taxa with different life history strategies. In an effort to bridge this gap, we investigated spawning periodicity and synchrony among 26 sympatric species of free-spawning, capsule-laying, and brood-protecting macroinvertebrates belonging to six different phyla. Twenty-four of these species released gametes or larvae between early March and late April. We analyzed the events over fine temporal scales to test the hypothesis that breeding activities were not random in time or relative to each other. We found that the two main reproductive pulses followed a lunar periodicity and that consistent species- and gender-specific modulations in the timing of spawning occurred during same-day episodes involving up to six free-spawning species. Mass spawning accounts from the literature were reviewed and compared. This work suggests that many species participate in synchronous heterospecific spawning events either because they respond to the same environmental cues or rely on cross-cueing and that reproductive isolation is favored by species-specific circadian patterns, spawning behaviors and cross-gender signaling.

Habitat, growth and predation as key factors in fishery management of *Cucumaria frondosa* (Echinodermata: Holothuroidea)

J.J. So, J.-F. Hamel and A. Mercier

Fisheries Management and Ecology 17:473–484 (2010). http://www.mun.ca/osc/mercier/Pages_from_Fish_Manag_Ecol_2010.pdf

Biological traits of the sea cucumber *Cucumaria frondosa* (Gunnerus) relevant to both ecological and management perspectives were investigated in the Newfoundland region. Abundance, size and fitness of adults were maximal on hard substrates. Larvae settled ~5 weeks post-spawning and juveniles reached a maximum length of 6 mm after 24 months. Additional size classes of sea cucumbers kept under natural environmental conditions exhibited slow seasonal growth attuned to phytoplankton blooms, indicating that ~25 years may be required to reach market size. Juveniles of the predator sea star *Solaster endeca* (L.) readily fed upon 1.5–2 mm long sea cucumbers. Predation rates on adult *C. frondosa* by adult *S. endeca* were modulated by temperature and biased towards injured specimens, suggesting that trawling may exacerbate predation pressure. The combination of slow growth and high predatory pressure enhanced by fishing activities emphasises the need for precautionary management of this emerging fishery in Atlantic Canada.

First record of the sea cucumber *Trachythyone nina* (Echinodermata: Holothuroidea) in Canadian waters with a redescription of the species and notes on its distribution and biology.

A. Mercier, D. Pawson, D.L. Pawson and J.-F. Hamel

Marine Biology Research 6:315–320. http://www.mun.ca/osc/mercier/Mar_Biol_Res_2010.pdf

The original and only description of the cucumariid holothurian species *Trachythyone nina* (Deichmann, 1930) is based on material collected near George's Bank, by the US Fish Commission Steamer Albatross 125 years ago. No additional material of this species has been formally reported ever since. We hereby record *T. nina* for the first time in Canadian waters, from several sites along the continental slope of Newfoundland and Labrador (43–55° N) at depths of 1088–1308 m and from the Arctic (60° N) at 590 m, as well as from two sites near the type locality at 132–155 m along the coast of New England. A more detailed and accurate description of the species is provided, along with notes on its ecology and distribution. This tiny (<15 mm long) gonochoric sea cucumber is usually associated with hard substrata, including deep-sea corals.

Endogenous and exogenous control of gametogenesis and spawning in echinoderms.

A. Mercier and J.-F. Hamel

Advances in Marine Biology 55:1–302 (2009)

Most echinoderms display seasonal or other temporal cycles of reproduction that presumably result from the complex interplay of endogenous and exogenous signals. Various environmental, chemical and hormonal factors, acting directly or indirectly, individually or in combination, have been proposed to cue, favour or modulate a suite of reproductive functions from the onset of gametogenesis to gamete release. From as early as the nineteenth century, an astonishing array of studies has been published on topics related to the control of reproduction in echinoderms, ranging from fortuitous behavioural observations to complex experimental demonstrations and molecular analyses. Although the exact pathways involved in the perception of external signals and their transduction into coordinated spawning events remain obscure for most species, significant advances have been made that shed new light on the information gathered over decades of research. By compiling the existing literature (over 1000 references), interpreting the main results, critically assessing the methodologies used and reviewing the emerging hypotheses, we endeavour to draw a clearer picture of the existing knowledge and to provide a framework for future investigation of the mechanisms that underlie reproductive strategies in echinoderms and, by extension, in other marine invertebrates.

Sea cucumber aquaculture in the Western Indian Ocean: Challenges for sustainable livelihood and stock improvement

H. Eriksson, G. Robinson, M.J. Slater and M. Troell

AMBIO. DOI: 10.1007/s13280-011-0195-8

The decline in sea cucumber fisheries that serve the Asian dried seafood market has prompted an increase in global sea cucumber aquaculture. The tropical sandfish (*Holothuria scabra*) has, in this context, been reared and produced with mixed success. In the Western Indian Ocean, villagers often participate in the export fishery for sea cucumbers as a source of income. However, with a growing concern of depleted stocks introduction of hatcheries to farm sandfish as a community livelihood and to replenish wild stocks is being promoted. This review identifies and discusses a number of aspects that constitute constraints or implications with regard to development of sandfish farming in the region. The conclusion is that for sandfish farming

to live up to its expectations the possible impacts need to be further studied, and that improved evaluation of ongoing projects is required. In the interim, a precautionary approach toward new enterprise activities is suggested.

Abstracts of the presentations of the 7th WIOMSA International Scientific Symposium, 24–29 October 2011 Mombasa, Kenya

Strengthening capacity for the sustainable management of the sea cucumber fisheries of the Western Indian Ocean: perspectives and main results from the regional MASMA project

Conand C. and Nyawira M.

The sea cucumber fisheries in the Indian Ocean contribute approximately 35% of the worldwide trade in beche-de-mer or trepang. Sea cucumbers in the western Indian Ocean (WIO) are mainly harvested for the export market, generate foreign exchange and also form an important component of livelihoods for local communities. However, increasing coastal populations, the high worldwide demand for beche-de-mer, the ease of collection in shallow coastal waters and the introduction of SCUBA, have combined to cause overfishing of this valuable resource. Despite their importance, information on the biology and ecology of sea cucumbers that is crucial for management is scarce. In an effort to address the challenges of the fishery, a MASMA project 'Sea cucumbers, a Poorly Understood but Important Coastal Resource: A Regional Analysis to Improve Management' was initiated in 2005 to improve our knowledge on these fisheries. The main components of the project included, species inventories and ecological studies, assessing the effectiveness of Marine Protected Areas in the management of sea cucumbers, studies on the reproductive biology of the key commercial species, studies on the socio-economics and management of the fishery and training in the taxonomy and fisheries biology of sea cucumbers. In this presentation, we update the status of the fisheries in the Indian Ocean focusing on the WIO region based on reported national statistics and information from various sources. The exports have declined in several countries and many other indicators show that over-exploitation seems to be main cause. Management interventions existing (or planned) at national level are often insufficient to protect the stocks, as illegal or unreported fisheries remain important. Suggestions for strengthening management at the national level are presented and regional and international agreements are recommended. The final report of the project is published in the WIOMSA Book Series.

Scales, mobility and learning: A regional perspective on management of sea cucumber fisheries

H. Eriksson, de la Torre Castro M., O. Per and N Kautsky

The sea cucumber fishery for export of beche-de-mer to Asian consumers is common across the Western Indian Ocean region. Coastal communities and nations have benefited from this activity for a long period of time, yet it seems that management has not kept up with the rate of development of the fishery as seen by the many reports of overfishing. In addition, informed management decisions are made difficult due to knowledge gaps in ecology and the data poor situation of the fishery. We here analyse the scales of the fishery and trade using data collected by participatory methods and stock census from two islands in the region (i.e. Zanzibar and Mayotte). Firstly, our results show that due to the lack of management in Zanzibar, and the associated depletion of coastal stocks, a new fishery beside the "traditional" village fishery has evolved – the industrial mobile fishery that operate with scuba gear to target new and remote areas and depths. This roving bandit style operation undermines fishing opportunities for coastal fishers, it undermines management efforts in nearby nations, and poses a threat to the ecosystem. In addition, it seems that Zanzibar upholds a trade network that captures catch and products from around the region. This illustrates the regional structure of the fishery and calls for a regional approach for management. Secondly when we compare the situation in Zanzibar to the heavily controlled fishing situation in Mayotte we find large differences in commercial stock value. We use our results to elaborate on the need for a regional governance regime and institutional measures to eradicate illegal fishing in order to allow the fishery to contribute to village economies to its full potential and prevent large-scale ecological degradation.

Spatial distribution of sea cucumbers in protected exploited areas of Unguja Island, Zanzibar

R. Mkenda, C. Muhando and N.S. Jiddawi

Zanzibar long term fisheries catch statistics show that sea cucumber catches are declining (probably over-exploited) in most of the shallow coastal waters around Unguja Island. This observation, however, is not verified or backed up by field data. In this study, the distribution pattern and stock sizes (density) of these organisms in zones open for collection in Menai Bay area and in fully closed Chumbe marine reserve was assessed. Information was obtained through interviewed local fishers and visual census (manta tows and

scuba dives). ArcMAP 9.3 software was used to visualize the distribution patterns and production of thematic maps for different sea cucumber species with respect to respective habitat characteristics. The Shannon Weaver Diversity for sea cucumber species was highest in Chumbe reserve ($H' = 1.585$). The high and medium value commercial species (*Holothuria fuscogilva*, *Stichopus herrmanni*, *Thelenota ananas* and *Thelenota anax*) were only encountered in Chumbe reserve while the other sites were mainly composed of low value species and at low density. The ANOVA Single factor showed significantly higher densities of *Holothuria atra* ($F = (5,132)$, $DF = 5$, $P = 0.0004$) and *Bohadschia graeffei* ($F = 2.815$, $DF = 4$, $P = 0.028$) in the reserve. However, there was no significant difference in densities of *Holothuria edulis* and *Stichopus monotuberculatus* among the sites. This study provides field evidence that commercially important sea cucumber species in the study areas are rare, most likely over-exploited. There is an urgent need for a proper management scheme to protect sea cucumbers (the high value species in particular) from high exploitation levels in most of the shallow waters around Unguja Island.

Community-led sea cucumber aquaculture in mainland Tanzania – Drivers and expectations

S.J. Matt, Y. Mgaya and S.M. Stead

We identify current gaps in socio-economic knowledge needed for aquaculture to fully optimise its potential in addressing food security science/policy research to support sustainable management of marine ecosystems in Tanzania. Empirical evidence is missing to test whether aquaculture can be an attractive and viable livelihood to offer to fishing communities traditionally dependent on marine ecosystems. We outline findings linking attitudes, perceptions and socio-economic factors as variables to determine communities' willingness to embrace sea cucumber aquaculture. Face-to-face interviews were carried out with coastal village heads of households in two peri-urban and one countryside village in Tanzania (Buyuni, Kunduchi and Ununio – $n=299$). Data collected described livelihoods, perceptions of marine health and governing instruments, economic status along with willingness to include aquaculture in livelihood activities. Material style of life and nine further explanatory variables were tested for significant explanatory strength by fitting a logistic regression model to the probability of respondents being willing to participate in aquaculture. Gender and occupation were significantly related to likelihood of aquaculture uptake. Likelihood of uptake was significantly higher amongst fishermen and farmers than all other primary occupations and higher amongst males than females. Potential earnings were identified as primary incentive for commitment to becoming involved, however expected earnings were comparable with modest income estimates for aquaculture. Despite stated willingness, less than 5% of respondents considered aquaculture a desirable future occupation for their children and only 18% of respondents said the same of fishing, indicating a general lack of esteem and/or perceived future prospects in coastal livelihoods. For aquaculture to realise its potential as a livelihood in fishing communities socio-economic research that captures attitudes and perceptions of targeted communities needs to be included as part of policy making to provide the corresponding context for governance that seeks wide stakeholder support.

Abstracts of posters

Assessing spatial population structure of Seychelles sea cucumber stocks based on fishing effort, habitats, and refugia

K. Haruko, J. Robinson, P. Usseglio and A. Friedlander

Sea cucumbers targeted for "beche de mer" are currently being overfished throughout the world. Its ease in harvesting coupled with recent increases in demand has led many local stocks to become commercially extinct. Seychelles sea cucumber fishery provides a unique opportunity to measure fishery impact on sea cucumber stock density and its distribution since the fishery keeps track of their spatial fishing effort. The project plans to survey the main granitic islands of Seychelles for stock size structure/density data, habitat data, as well as fishing effort data spanning over several consecutive years and produce spatially explicit population dynamic models to aid future stock management. Seychelles sea cucumber fishery is solely operated with SCUBA, thus it is hypothesized to create a natural refugia for the population inhabiting deeper than 40 m. Additionally, Seychelles has set various MPAs around their islands. These combined allow a rare opportunity to study the impact of fishery and its relationship to refugia. The project collected fishery log data, VMS data, port location, habitat data, fishery independent survey data for each commercially targeted species, which then were incorporated into GIS for further analysis and modeling. Size structure and densities were analyzed to assess its relationship to various habitat types and fishing intensity. The project also assessed the quality of habitat map created from hyper-spectral satellite imageries (Hyperion) using the collected data. The preliminary result from the first year of field season will be presented.

Optimization of the sea cucumber farming within the Madagascar Holothurie SA company

T. Lavitra, P.G. Justin, J.C. Kit, O. Méraud, M.W. Rabenevanana, I. Eeckhaut

Holothuria scabra, commonly known as sandfish is one of the most prized and valuable sea cucumber species among the tropical species. Consequently, it is also one over-exploited in the Indo–Pacific region. However, several studies and project proved that this holothurian is the most promising in aquaculture. Madagascar Holothurie SA (MHSA) is the first trade company based on sea cucumber aquaculture in Madagascar and involves the coastal villagers. Created on April 2008, the society aims to produce 100 000 *H. scabra* juveniles per year. During the 3 years of its existence, several rearing parameters have been optimized as well in the hatchery as in the nursery ponds. This optimization includes (i) the use of gonads collected directly from collector villagers (ii) the finding of optimal rearing density at each developmental stage of *H. scabra*, (iii) the selecting and regrouping of the batch header in one rearing tank for the epibenthic juveniles stage, (iv) the use of the greenhouse for the nursery ponds during the fresh season and (v) the reduction of the layer of sediment used for endobenthic juveniles stage. The results show that, the average production yield of *H. scabra* juveniles increased from 1584 individuals per month on 2008 to 3738 on 2009 and 5148 on 2010. The company stopped to buy broodstocks since May 2010. The amount of the sediment used for the nursery ponds decreased from 4 cm deep on 2008 to 0,5 cm from April 2010. The results obtained from these 3 years of the existence of MHSA are very promising and now the company prepares the industrial level and expects to produce 4 to 5 millions of *H. scabra* juveniles for the next years

Development of multi–stakeholder *Holothuria scabra* aquaculture forum in Madagascar: a promising tool to promote best practice and information sharing

A. Rougier and S. Peabody

Village based aquaculture of sea cucumbers *Holothuria scabra*, first pioneered in southwest Madagascar in 2008, is gathering momentum as a viable sustainable alternative livelihood for traditional Vezo fishing communities. Following renewed investment in hatchery capacity in the regional capital Toliara, as well as in community–based grow–out pens and capacity building, this ambitious mariculture initiative now involves a number of different stakeholders working together to develop this aquaculture technology as a viable business for communities and private sector hatchery investors alike. Recognising the need for coordination of activities amongst the different actors involved in this new initiative, at both hatchery and community levels, a regional forum was established to bring together all sea cucumber aquaculture stakeholders in the region, to share and discuss experiences, lessons learned and best practices from their respective activities. The forum, which meets every month, is based on open discussions and roundtable workshops, provides an important platform for exchanging experiences and challenges amongst the diverse stakeholders in the rapidly evolving sea cucumber aquaculture sector. The current favoured model for community–based ranching of hatchery–reared sea cucumbers, which has already been adapted, refined and improvement based on the experiences of conservation NGO Blue Ventures and its partners, is now being replicated by other actors in this region, and sharing experiences through the regional platform offers a vital means for others to learn more quickly the lessons gained from projects already in progress. Based on the progress of the Toliara sea cucumber aquaculture platform, experiences indicate that there is considerable potential for replication of such a stakeholders’ forum to improve the adaptive management of other fishery and aquaculture sectors in Madagascar and the broader western Indian Ocean region

Sea cucumber fishery in Seychelles - Spatail expansion effect on populations

H. Koike, J. Robinson, P. Usseglio and A. Friedlander

Sea cucumbers targeted as “beche de mer” are currently being overfished throughout the world. Its ease in harvesting coupled with recent increases in demand has led many local stocks to become commercially extinct. Seychelles’ sea cucumber fishery provides a unique opportunity to measure fishery impact on sea cucumber stock density and its distribution since the government keeps track of its fishery’s spatial fishing effort and catch. This project surveyed the main granitic islands of Seychelles to identify each species’ size structure, density, and habitat preference. Fishing effort data from the fishery log was combined to assess the relationship between fishing intensity and the surveyed variables. The fishery landing data coupled with fishing effort was also analyzed to evaluate the effect of spatial expansion of the fishery. Canonical correspondence analysis showed sand fish and white teatfish preferred to occur in sandy area whereas black teatfish preferred to occur in coral rubble area. It also showed that fishermen preferred to fish in sandy habitat thus catching more white teatfish which agreed with the catch report. Nonmetric multidimensional scaling showed that larger size of black teatfish were found in deeper less fished area. The fishery log analysis additionally showed that increase in catch was compensated by spatial expansion of the fishing effort.

Community based *Holothuria scabra* farming in South West of Madagascar: lessons learned and improvement of approaches of Blue Ventures' project

A. Rougier, S. Peabody and S. Benbow

The first trials of village-based sea cucumber aquaculture in the western Indian Ocean were conducted in southwest Madagascar following an academic research partnership between the universities of Mons, Toliara and the Université Libre de Bruxelles. This partnership helped establish the region's first hatchery for the sandfish *Holothuria scabra*. Since 2008, conservation NGO Blue Ventures, working in partnership with MHSA, a spin-off company from the research project and holder of the patent on the in vitro hatchery process used to cultivate *H. scabra* juveniles, launched a preliminary village-based aquaculture project that included the Velondriake locally managed marine area (LMMA). The integration of marine aquaculture into the protected area was aimed to provide communities with sustainable and lucrative alternative activities to fishing. The first two years of the project served to establish a strong base for community-based aquaculture of *H. scabra* in the area, as well as to identify the various technical and socioeconomic limitations of the original model for community-based ranching. With new funding for expansion of this project within Velondriake to at least 2013, partners are now working to capitalise on the good farming practices identified during the preliminary project, as well as overcome challenges encountered in the initial trials, notably to develop tools to prevent poaching and better integrate aquaculture of sea cucumber farming amongst local livelihoods within coastal communities of the region. Through adaptive management based on ongoing analysis of problems encountered by Blue Ventures' researchers and technicians, coupled with a participatory approach to engage communities in all aspects of the project, and a strong dialogue with all stakeholders, a refined farming model has evolved. This new production system, in constant improvement, offers strong opportunities for sustainable income generation for community farmers, and is potentially replicable in many coastal areas of this region.

PhD Dissertation

Assessment and management of sea cucumber resources in the coastal waters of Sri Lanka

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This thesis addresses the stock status of commercial sea cucumber species in the coastal waters of Sri Lanka and possible management measures to ensure their sustainable utilization. The stock status of commercial sea cucumbers was evaluated using data collected from an Underwater Visual Census (UVC) and fishery dependent surveys carried out off the east and northwest coasts of Sri Lanka in 2008 and 2009. Of the 25 sea cucumber species identified, 21 species are commercially important and 11 species were predominant in the commercial catches. The total abundance of sea cucumbers was higher off the northwest coast (62.3×10^6 nos) than the east coast (11.9×10^6 nos) and low-value species were predominant in both survey areas. *Holothuria edulis* was the most abundant species in numbers while *Holothuria atra* had the highest stock biomass. In both regions, commercial fishery predominantly relies on two nocturnal species: *Holothuria spinifera* and *Thelenota anax*. *H. spinifera* had the highest contribution (73%) to the total landings off the northwest coast while this was provided by from *T. anax* (93%) off the east coast. Density estimates indicate that all the sea cucumber stocks in the coastal waters of Sri Lanka are at critical level (<30 ind ha^{-1}) except for 3 stocks (*H. atra*, *H. edulis* and *H. spinifera*) off the northwest coast and one stock (*H. edulis*) off the east coast.

Biological aspects of *H. atra* and *H. edulis*, which were found to have potential to contribute to future fisheries, were further investigated. High densities of *H. atra* were found in the shallow (<10 m) seagrass beds and *H. edulis* was commonly reported in shallow reef flats and rocky habitat. Although these two species favoured a similar range of sediment mean grain size (0.7-1.2 mm) and gravel content (15-25%), they have different preferences towards the sediment organic content making it possible for them to have separate niches. When the reproductive biology of *H. atra* was evaluated using gonadosomatic indices and histology of gonads, a synchronous seasonal gametogenesis with some asynchrony among individuals was revealed. Further, this population was sexually active throughout the year having peak spawning in April and October. The main spawning event coincided with the highest temperatures and the size at first sexual maturity of *H. atra* was 16 cm.

Estimates of average natural mortality (M) for sea cucumbers are important findings of this study. Two approaches; simple linear regression and random effects models, were used in this analysis and the estimated values were $0.50 yr^{-1}$ and $0.45 yr^{-1}$, respectively. The random effects model predicted lower natural mortality (M) for nocturnal species than for the diurnal species.

A number of possible management measures were identified, including limiting the exploitation of some commercial species, setting of total allowable catch (TAC) limit and minimum landing size (particularly for highly abundant species), implementation of routine monitoring, reporting of commercial landings and implementation

of marine protected areas (MPAs). A multi-area bulk biomass model was used to design MPAs off the east coast of Sri Lanka and spatial management through marine reserves is seen to have potential to rebuild the highly depleted sea cucumber populations. Apart from the management of local sea cucumber resources, the information gained through this study is important for updating the regional and global sea cucumber catch statistics as well as to contribute information for the implementation of regional management programmes.

Master's thesis

Estimation des stocks d'holothuries commerciales dans le lagon de Moorea et recommandations de gestion associées

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Holothurians are eaten by Asian populations since ancient times and are therefore fished in many Pacific islands. In the lagoon of Moorea, five species are now harvested and have been studied to get an estimation of their stock size. Sea cucumbers were surveyed in the lagoon, the reef crest and passes, along transects. In order to correlate the number of individuals and the biomass, size-to-weight relationships from the literature were used, except for *Bohadschia argus*, for which the relationship was established in collaboration with the wholesaler from Moorea. Ecological preferences for each species were also studied. The data set provides management advices to sustainably preserve this marine resource. As a result, recommended quotas (kg of gutted weight/year) and minimum harvestable sizes (cm) are as follow: *Bohadschia argus* (11,430 kg, 35 cm), *Thelenota ananas* (6 kg, 30 cm), *Holothuria fuscogilva* (241 kg, 35 cm), *Holothuria whitmaei* (52 kg, 30 cm) and *Actinopyga mauritiana* (75 kg, 17 cm). These recommendations could be included in de Management Plan of the Maritime Area of Moorea. Fishing gear restriction and regulation for all actors of the sea cucumber's fishery are also recommended.

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