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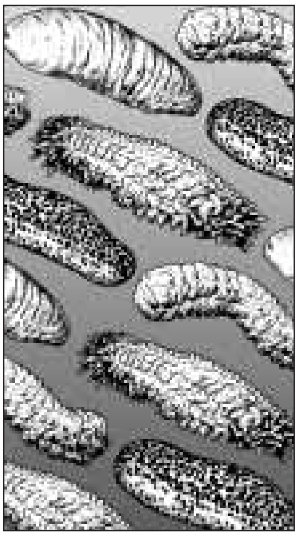

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EDITORIAL

Welcome to the 16th issue of the Bulletin. In this issue, Steve Purcell et al. present the three-year ICLARM project on Optimal Release Strategies for Sea Cucumbers. This project has started its activities at SPC Noumea and aims to determine the best strategies for releasing sandfish (*Holothuria scabra*) into the wild for the purpose of restocking and stock enhancement of inshore Pacific fisheries.

Also in this issue, an article by Mike Trianni, from the CNMI Division of Fish and Wildlife, describes a sea cucumber fishery that took place between October 1995 and May 1996 on the island of Rota. You will also find articles about the sexual reproduction and farming of larvae of a little-studied species in India and about *Apostichopus japonicus* larvae.

Abstracts of the sea cucumbers presentations made during the 6th European Conference on Echinoderms in Banyuls (2001) and other press articles are also included in this issue.

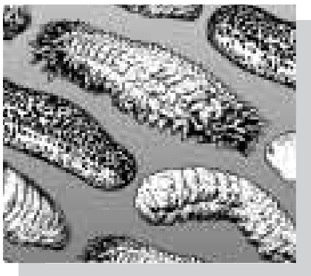
Previous issues of the Bulletin are available on the SPC web site at www.spc.int/coastfish/ in both French and English. Issue no. 26 of the Echinoderms Newsletter is now also available on the Web at www.nmnh.si.edu/iz/echinoderm.

An echinoderms forum was created after the International Conference in Dunedin. You can subscribe to it by contacting sabine.strohr@nrm.se or by sending an email to listserv@nrm.se and including on the first line of the message SUBSCRIBE ECHINODERM-L, your surname and first name, but no other text.

Please do not hesitate to send me your comments or suggestions in order to make this bulletin more interesting and useful.

Chantal Conand

Inside this issue



new info
beche-de-mer

Developing optimal strategies for restocking sandfish: a collaborative project in New Caledonia

Steve Purcell,[1] Deborah Gardner[1] and Johann Bell[2]

Background

Sea cucumbers, processed into beche-de-mer, are a valuable resource for coastal communities in the Pacific. In the case of New Caledonia, there is a long history of fishing for sea cucumbers, dating back to the 1840s (Conand 1990). The fishery is currently composed of mainly indigenous and artisanal fishers. The price offered to fishers for sea cucumbers varies from about USD 0.60 to 2.20 per kilo for whole, fresh animals.

The increased fishing pressure for sea cucumbers in the Pacific is fuelled by the increasing wholesale price of first-grade product, such as well-prepared sandfish, *Holothuria scabra* (Fig. 1). In the year 2000, a total of 62 metric tonnes of dried beche-de-mer was exported from New Caledonia (Observatoire Economique, New Caledonia), where sea cucumbers are still abundant. However, in other places in the Pacific and South-East Asia there has been severe over-fishing of high-value species, such as *H. scabra*, and it is now apparent that depleted stocks can take decades to recover.

It is encouraging to see that many Pacific Island countries are now embracing the idea of marine reserves or Marine Protected Areas (MPAs) to protect some parent stock as a source of egg production for depleted inshore areas. However, numbers of sea cucumbers may be too low in some areas to constitute viable breeding populations. Recent advances in aquaculture now allow the culture of sea cucumbers to a small size in hatcheries, and this process offers a way to restock inshore habitats with valuable species. ICLARM – The World Fish Center recently completed a three-year project in Solomon Islands, which found that *H. scabra* is the species most suited to restocking in the tropical Pacific and South Asia. The project established the methods for rearing juvenile sandfish en masse in simple, land-based nursery systems.

Figure 1. Dried sandfish from New Caledonia, for export.

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Project overview

The second phase of the research program will use New Caledonia as the study location. It aims to find the most effective ways to release hatchery-produced juvenile sandfish into shallow reef/inshore habitats so that a high proportion of them survive to repopulate depleted areas. Broodstock are available from local waters and large adults can be found in both colour morphs at some sites (Fig. 2).

Figure 2. Broodstock of both colour morphs of *H. scabra* collected near Noumea.

The project is being conducted in partnership with the Secretariat of the Pacific Community (SPC) and is funded by the Australian Centre for Agricultural Research (ACIAR), the Provinces of New Caledonia, and the French Government.

Culture methodology

The project will culture sandfish at the hatchery at St Vincent, north of Noumea, and later at Foue in the Northern Province. We will apply methods of larval rearing, settlement and grow-out established previously and described by Pitt (2001). Figure 3 shows the culture steps and duration that will be employed in New Caledonia. On arrival at the hatchery, broodstock are weighed (Fig. 4), then sexed via biopsy to determine the sex ratio of the sample group. Groups of 30–60 animals will be induced to spawn using temperature shock.

The fertilised eggs will be collected, rinsed and transferred to 60- or 250-l plastic incubators with filtered seawater. After hatching (~12–24 hrs), the auricularia larvae will be placed into 1000-l conical tanks. High turbidity of intake water at the hatchery is a potential problem, addressed by using storage water, possibly treated with antibiotics and/or EDTA (5 ppm).

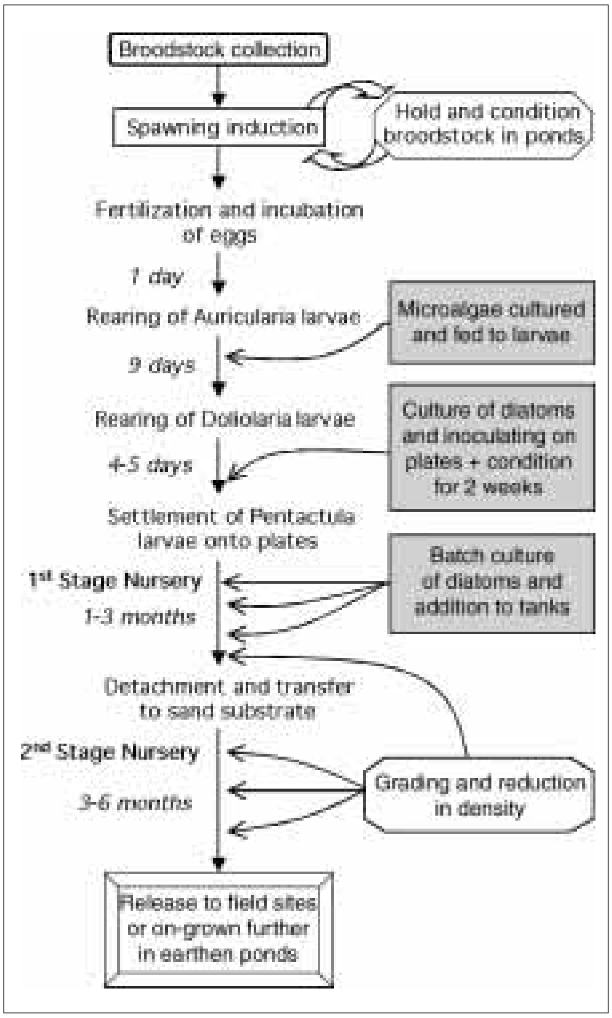

Figure 3. Flow chart of stages of sandfish hatchery culture.

Figure 4. Large broodstock *H. scabra* being weighed at St Vincent hatchery.

The auricularia larvae will be fed a variety of microalgae including *Rhodomonas salina*, *Chaetoceros muelleri*, *C. gracilis*, *C. calictrans*, and *Platymonas* sp. The pentactula larvae should be competent to settle after 14 days, at which time stacks of diatom-coated PVC plates (600 mm x 300 mm) will be introduced to induce metamorphosis and provide settlement substrata. Alternatively, competent larvae may be transferred directly into raceways containing the diatom-coated plates.

Juveniles can be grown in these tanks for about three months, when they are expected to reach 10–20 mm in length, or 1 g. Stocking density is then reduced from 400 to around 130 juveniles m^{-2}, through successive grading. Control of copepods via the use of insecticide is also a likely requirement.

At 20 mm in length, juveniles will be placed onto a sand substrate in canvas raceways, ponds or pens in the inshore waters and grown for a further 2–3 months until they reach 60 mm or 20 g. Density at this stage is further reduced to 10 juveniles m^{-2}. Additionally, the aquaculture component will examine broodstock conditioning and tagging, validating gonad biopsy methods, simplification of the larval feeding regime, and intensification of the first and second nursery stages.

Research programme

Tens of thousands of hatchery-produced juvenile *H. scabra* will be released in successive field experiments to identify the best transportation methods, size and density for release, release habitat, release time, and release season. The partnership with SPC will greatly facilitate dissemination of the findings through SPC's international fishery meetings, regional aquaculture strategy, and links with the University of the South Pacific.

Stock assessments of sandfish in New Caledonia will be conducted and linked to existing GIS data on habitat types in the lagoon from ZoNéCo (Zone économique de Nouvelle Calédonie), a local multidisciplinary programme for marine resources.

Short-term experiments will test different methods for transporting juveniles to release sites and fence enclosures will be trialled as a method for improving recaptures and survival of juveniles. Survival of released juveniles will be tested in potential release habitats, including deep and shallow sandy areas with and without seagrass.

The subsequent experiment will determine the optimum size and density of juveniles for release, allowing a cost-benefit analysis of the best trade-off between production costs and survival. A further experiment will examine the survival of juveniles released at different times of the day and year.

We plan to conduct tank- and pond-based experiments to examine conditions for scaling-up the production of juveniles and for culturing sandfish with shrimp, which forms an aquaculture industry in New Caledonia. The experiments will complement current work by Rayner Pitt in Vietnam through ICLARM – The World Fish Center.

Collaborative work with the Australian Institute of Marine Science (AIMS), in Australia, will determine the genetic structure of sandfish stocks from the Provinces of New Caledonia and perhaps develop a genetic tag for restocked animals. Juveniles will be tested for disease by scientists from IFREMER and quarantined if necessary.

Project vision

In many countries, over-fishing of sandfish has caused a loss of income and a switch to fishing for species of sea cucumber of lower value. This project aims to supply a comprehensive outline of the methods for restocking sandfish in areas that have been, or may become, over-fished. In addition, there is ample scope for local communities to become involved in 'ranching' sandfish in fence enclosures at low cost and with little maintenance.

By examining the co-culture of sandfish with shrimp, the project will reveal strategies for producing by-crop species for shrimp aquaculture industries. Once definitive results of the methods and viability of co-culture are obtained, the technology can be progressively transferred to shrimp growers for large-scale culture. Co-culture may ultimately improve yields of shrimp to the industry because the digestion of organic waste products by sandfish has the capacity to improve pond conditions.

This is contribution number 1651 of ICLARM – The World Fish Center.

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Summary of data collected from the sea cucumber fishery on Rota, Commonwealth of the Northern Mariana Islands

Michael S. Trianni[1]

Abstract

A sea cucumber fishery in the Commonwealth of the Northern Mariana Islands (CNMI) began in October 1995 on the island of Rota, and continued through May 1996, when the company began preparations to move operations to the island of Saipan. In January 1996 the CNMI Division of Fish and Wildlife required the harvest company to submit harvest and financial data. Examination of the submitted data identified inaccuracies, such as the lumping of the two target species, the surf redfish, *Actinopyga mauritiana*, and the black teatfish, *Holothuria whitmaei*. Summary of the data set revealed trends in catch that showed an increase in catch per unit effort over time, concluded to be a result of calmer weather conditions providing access to previously unharvested areas. Mean dried weight data were used to estimate the number of sea cucumbers harvested prior to the data collection programme. The estimated number harvested was 148,950. Product recovery data were also examined. It was concluded that sound regulations and preliminary harvest surveys are necessary to ensure coherent management.

Introduction

Throughout Micronesia sea cucumbers were harvested on a commercial scale during the Japanese Mandate years although the specific species harvested were not identified in export records (Smith 1947). The harvest was estimated at 20–30 tonnes per year, with the chief centres of production being Saipan (6%), Palau (18%), Yap (4%), Chuuk (61%), and Pohnpei (11%) (Smith 1947). Richmond (1995) estimated that over 30,000,000 sea cucumbers were harvested during those years, and suggested that areas around Chuuk have yet to recover from the high exploitation rates of the 1920s and 1930s. In reference to Micronesia, Smith (1947) stated, 'According to Japanese reports, overfishing had reduced the numbers in many places, as no conservation regulations applied to these animals. Our own observations tended to confirm the Japanese statements, as the larger and more desirable commercial species were not very abundant compared with the unutilised species.'

Descriptions of the sea cucumbers observed on the island of Saipan in the Mariana Islands by Smith (1947, 50–52) can be tentatively interpreted as the lolly fish, *Holothuria atra*, the greenfish, *Stichopus chloronotus*, the elephant trunkfish, *Holothuria fuscopunctata*, and probably the black teatfish, *Holothuria whitmaei* (formerly *H. nobilis,* Rowe and Gates 1995). The first two were found to be abundant in Saipan Lagoon in surveys conducted by Chandran (1988) and Duenas & Associates (1997), and both are listed as being of low commercial value (Conand 1990, SPC 1994).

Smith (1947) did not survey for sea cucumbers on the island of Rota and referenced Japanese Mandate harvests as from 'Saipan' only, perhaps due to Saipan being the probable port of export, rather than the only island where harvest occurred. He did mention that the local population did not consume sea cucumbers, but whether or not any commercial harvest occurred from Rota during that period was unknown. During the German occupancy of the Marianas (1899–1914) it was noted by a German district officer of Guam that Carolinians from Saipan dove for trepang at Aguigan Island off Tinian Island and sold them to Japanese merchants (Amesbury et al. 1989).

A commercial sea cucumber fishery began in the Commonwealth of the Northern Mariana Islands (CNMI) on the island of Rota (14°10' N, 145°14' E) in October 1995 (Fig. 1). The CNMI Division of Fish and Wildlife (DFW) became aware of the fishery in December 1995 and initiated data collection in January 1996 that continued until the end of May 1996 when the company, based in Guam of Chuukese origin, ceased harvest in anticipation of moving operations to the island of Saipan. This paper documents and summarises the data submitted to DFW from the Rota fishery.

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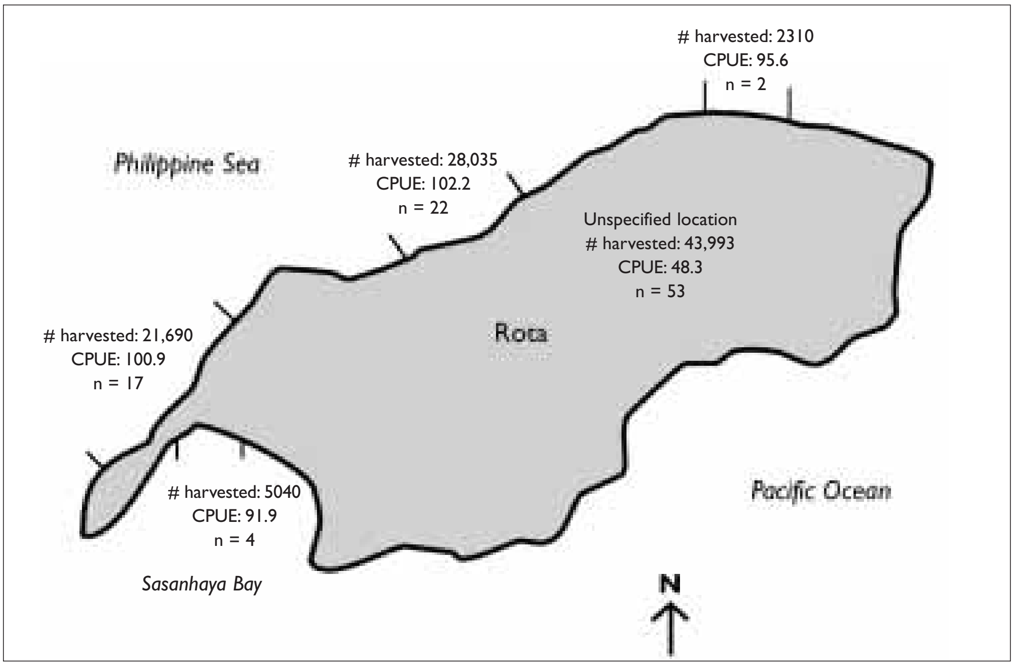

Figure 1. The island of Rota, Commonwealth of the Northern Mariana Islands.

Method

Data reporting

Beginning in January 1996 the harvest company was required to submit data to the DFW as an export permit condition. Data that were requested from the fishing company included the following:

- date of harvest
- location of harvest
- number of harvesters
- number of hours fished
- species harvested
- number harvested per species
- total live weight harvested per species
- total processed weight per species
- total weight exported
- gross and net revenues.

Data forms were created and provided to the company, along with the sea cucumber identification guide published by SPC (1994). A map was also provided to the company to document harvest locations.

Data collection took the form of requiring the company to submit these data statistics to the DFW office on Rota on a weekly basis. The data were then sent to Saipan where they were reviewed for completeness and stored in electronic format at the Saipan office.

The fishery

Harvest of sea cucumbers from the outer reef flat was completed by hand picking and placement in 6-gallon (22.7-litre) buckets, then transfer to a pickup truck for transportation to the processing facility. On the outer reef slope, sea cucumber harvest was accomplished by free diving, using a 14-foot (4.3-meter) outboard powered boat for transportation back to port. The use of scuba or hookah was prohibited by export permit condition. The harvest crew consisted of 3–5 Chuukese fishermen, plus a vessel operator when using the boat.

The catch was processed using the standard method outlined by SPC (1994). The sea cucumbers were gutted, boiled, smoked for 48 hours, suncured for 3–4 days, and then packaged for export.

Data quality

Managing the Rota fishery proved difficult, as no personnel could be dedicated to it on a daily basis. Problems with the submitted data were encountered in some of the data fields. These problems are outlined below.

Location of harvest

Nearly 55% of the harvest data did not specify harvest location, generalising location to 'Rota.'

Although measures were taken to resolve the problem, enforcement was not sufficient to cause the company to alter this practice until late in the fishery, when the company began negotiations to move their operation to Saipan. Data for the months of October through December were only submitted as the monthly totals of dried weight exported.

Species harvested and number harvested per species

The sea cucumbers harvested in the submitted data were listed as 'potatoes (brown)' for every entry except twice in February 1996, when 'black teatfish' were additionally recorded. Observation of the species identified as 'potatoes (brown)' indicated that they were the surf redfish, *Actinopyga mauritiana*. Grouping all sea cucumbers under a general term such as 'potatoes (brown)' masked the presence of the black teatfish harvested, as company personnel admitted to catching black teatfish when encountered. Direct observation of landings and of the smokehouse facility on Rota indicated that black teatfish were being harvested, albeit in low numbers, but not recorded on the data sheets. The total number of sea cucumbers harvested per trip was usually submitted as a rounded estimate (e.g. '680,' '1050,' '960').

Results and discussion

The estimated total number of sea cucumbers harvested in Rota from January though May 1996 was 103,193, with an estimated total wet weight of 75,492 lbs or 34,242 kg. The average weight per 'potatoes (brown)' was estimated at 0.73 lbs or 331 g, while black teatfish were estimated to average 3.5 lbs or 1588 g. The estimated total dried weight harvested was 10,826 lbs or 4910 kg.

The dried product weight of the first shipment of sea cucumbers harvested from Rota was 2177.3 kg, which included October through the first week of December 1995. With an overall estimated mean dried weight per sea cucumber of 0.0476 kg, the estimated number of sea cucumbers harvested in Rota prior to implementation of the DFW data collection programme was about 45,757, bringing the overall total to 148,950.

Zoutendyk (1989) collected surf redfish in Cook Islands for trial processing and marketing and found outer reef flat specimens to average 280 g, while reef slope specimens (1–3 meters depth) averaged 620 g. When compared to the average value of 331 g of Rota's 'potatoes (brown),' it suggests that the majority of 'potatoes (brown)' were probably surf redfish. Depth of harvest was provided for 78% of the harvest dates from Rota, in ranges such as 1–10 feet. It was therefore not possible to compare mean weights from different depths. If the data collected in Cook Islands by Zoutendyk (1989) were indicative of surf redfish size partitioning by habitat and depth, then the majority of surf redfish harvested in Rota were from the outer reef flat habitat. This would also be supported if the average weight were biased slightly upward due to the presence of unidentified black teatfish in some of the submitted harvest data.

Three export records from the Rota fishery were submitted to DFW as required under permit condition. These records documented that a total of over 6885 kg of sea cucumber were exported from the commercial port of Saipan to Hong Kong during 1995 and 1996 (Table 1).

Excluding the first shipment that was collected prior to company submittal of catch data, 4708 kg of sea cucumber from Rota were exported from the last two shipments, compared to the estimated dried harvest weight of 4910 kg for the similar time period submitted on the data forms. The difference may be explained by the time period of the last two shipments of sea cucumbers from Saipan, which also included sea cucumbers harvested on Rota during December 1995, prior to the January 1996 commencement of data collection.

The product recovery rate (percent of dried weight to initial weight as reported on the submitted data forms) for 'potatoes (brown)' from the Rota fishery was directly calculated as 14.34%. The average product recovery rate for the two documented harvests of black teatfish from the Rota fishery was 11.57%. The product recovery rate for surf redfish from other studies in the Pacific region varied from

Table 1. Exports of Rota harvested sea cucumbers from the port of Saipan.

Date to Saipan	Date to buyer	Destination	Shipment weight (kg)
10/12/95	16/12/95	HongKong	2,177.3
10/03/96	14/03/96	HongKong	1,562.6
1/06/96	23/06/96	HongKong	3,145.7
Total			**6,885.6**

5% to 10% (Table 2), while SPC (1994) listed the product recovery rate of the black teatfish as 8%. Inclusion of the black teatfish data lowered the overall average product recovery rate to 14.23%. Conand (1990) presented changes in length and weight for six species of sea cucumber during four stages of processing, 'initial condition,' 'after boiling,' 'smoking,' and 'dried product.' She attributed the variation of dried product weight from the various studies referred to a result of remaining moisture content. Data for the surf redfish were not presented, although data were presented for the deepwater redfish, *Actinopyga echinites*, a morphologically similar species that is replaced by the surf redfish on the outer reef flats (Rowe and Doty 1977, Kerr et al. 1993). Data presented by Conand (1990) for this species showed that the recovery rate following smoking was 16%, and following drying from 3–11%. The data from Rota suggested that 'dried weight' as submitted on the data forms could have been the weight following smoking.

Table 2. Comparisons of product recovery rates for the 'potatoes (brown)' from the Rota fishery and the surf redfish, *A. mauritiana*, from other studies.

Product recovery rate (%)	Source
14.34	Rota fishery data
7.0	Zoutendyk (1989)
5.0	Veikila and Viala (1990)
8–10	Din (1986)

Another possibility was that the sea cucumbers exported from Rota may have been of a low grade due to a high moisture content. The average price per kg as calculated from the submitted financial data was USD 7.74. By comparison, the reference price for 'Grade-A' surf redfish in Singapore in 1996 was USD 12.00–15.00, and 'Grade-A' black teatfish USD 20.00–25.00 (SPC 1997). Preston (1993) lists the mid-1990 export price of surf redfish at USD 7.00–8.00/kg and the black teatfish USD 11.00–12.00.

The mean catch per unit effort (CPUE) per month as the number of sea cucumbers harvested per collector-hour, and the number landed per month from the fishery, both calculated from submitted data, are illustrated in Fig. 2. Dalzell et al. (1996) listed CPUE as the number of pieces harvested per collector-hour for a variety of sea cucumber species, except the surf redfish. The black teatfish CPUE were very low, between 6.0 and 19.2, while mean values for *A. miliaris* and *A. echinities* ranged from 68.2 to 118.0. The daily CPUE in the Rota fishery varied from 34.0 to 133.6, with a mean of 72.2. Text in Fig. 1 shows the mean CPUE for harvest locations on Rota. Except for data from the unspecified harvest location, which had the lowest CPUE, the location specified CPUE data were from harvests during April and May 1996.

Both CPUE and landings increased during April and May, toward the end of the fishery, concurrent with the advent of spring doldrum conditions resulting in calmer seas that may have provided easier access to reef areas previously unexploited due to poor sea conditions. The geographic orientation of Rota does not provide for extensive lee aspects, resulting in significant surge in nearshore areas most of year, particularly during the months from September through December, when typhoon activity is at a peak in the Mariana Islands.

The lack of CPUE data from the early months of the fishery as well as the lack of location data for about 55% of the submitted data precluded any analysis of trends per area. The CPUE within the same month from unspecified locations were compared to those where location was specified in Fig. 3. The unspecified location CPUE were much lower than the specified location CPUE, even in months where both types were submitted, although the CPUE for specified location from February 1996 was comprised of only two harvests. The data in Fig. 3 would seem to support the premise that previously unexploited areas were accessed in April and May 1996. Despite the increase in CPUE over time the number of sea cucumbers harvested must have been significant to cause the company to shift operations to Saipan, indicating overexploitation. A post-harvest survey was not conducted due to limited human resources and the commencement of the Saipan fishery.

Callaghan (1995) presented an economic analysis for a hypothetical sea cucumber harvest in Micronesia by subsistence or artisanal fishermen, based on a harvest of 100 sea cucumbers sized 10 per kg dry weight, per eight hour fishing trip by two fishermen using a 16–18 foot outboard powered vessel. That analysis indicated that net revenue would fall as the size of sea cucumbers became smaller, with substantial net revenue occurring only in size categories of 10 and 20 per kg dry weight. It was found that harvests resulting in more than 30 sea cucumbers per kg dry weight were not economically viable.

The fishery in Rota was conducted by an outside commercial venture comprised of fishermen with harvest experience from other parts of Micronesia. If the size categories from Callaghan (1995) are applied to these data it can be observed in Fig. 4 that

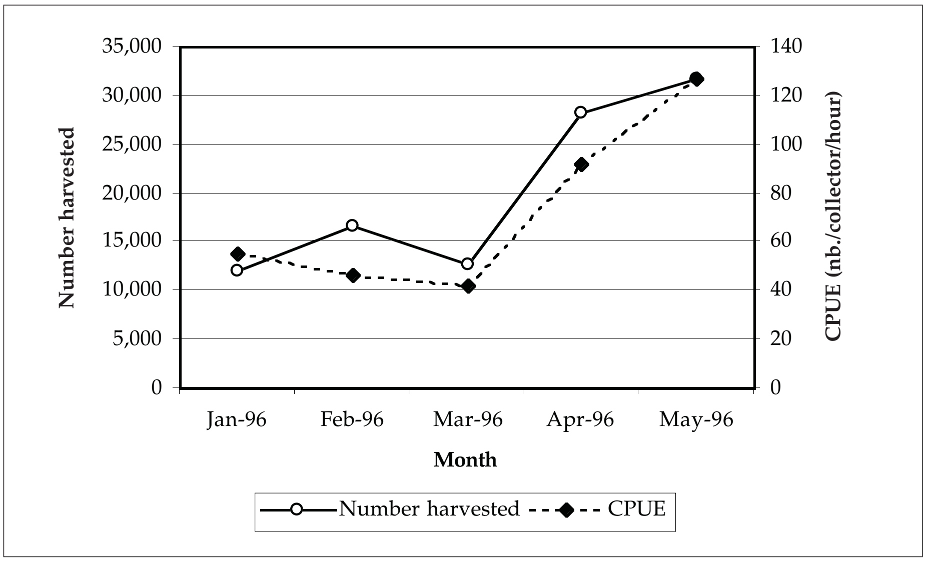

Figure 2. Total number of sea cucumbers harvested and CPUE for the Rota fishery.

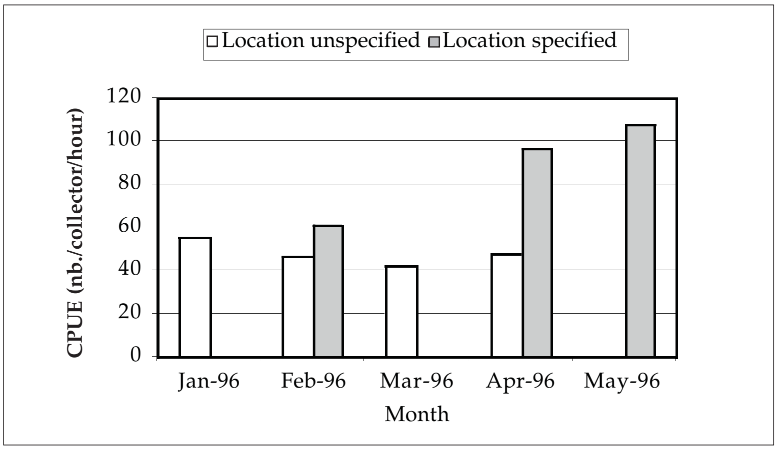

Figure 3. Comparison of CPUE for unspecified harvest location versus specified harvest location.

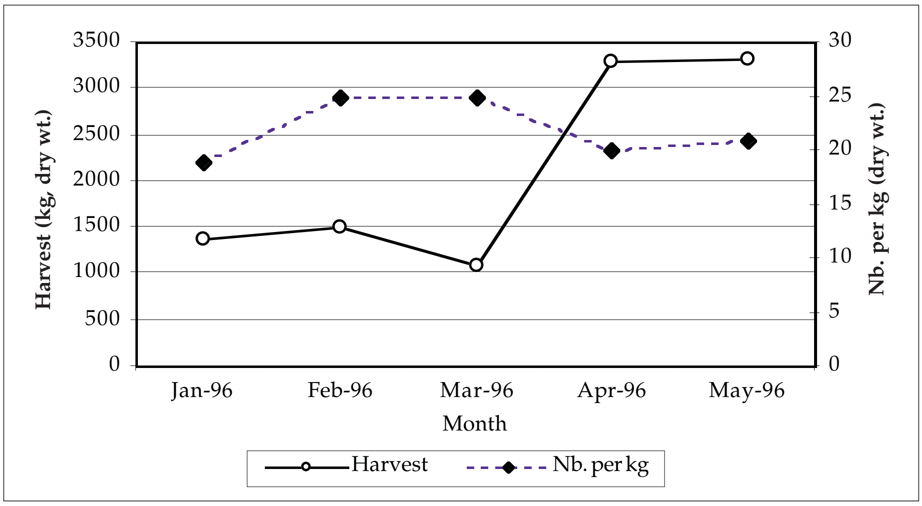

Figure 4. Total dry weight of sea cucumber harvest and mean number of individuals per kilogram of dry weight.

the 30 individuals per kg dry weight cut-off point was never attained in the Rota fishery. The highest number recorded was 25 per kg dry weight for the months of February and March 1996. During those months the lowest CPUE values were also documented (Fig. 2). Although harvest location information was not available for February and March 1996, based on data in Figs. 2–4 it appeared that some areas on Rota were probably overexploited, and previously unexploited areas were harvested during April and May 1996.

Conclusion

The data resulting from the Rota fishery indicated that the company initially had harvest success at the commencement of the fishery followed by a drop in harvest rates, due to a probable combination of seasonal conditions and over-exploitation of accessible areas. With the seasonal advent of calmer seas previously unexploited areas were targeted, resulting in high harvest rates.

The lack of any catch data from the first three months of the fishery, as well as the lack of harvest location data in nearly 55% of the reported data, hampered a more coherent analysis.

The economic model produced by Callaghan (1995) suggested an economic size limit on harvest, although the level of economic viability of a sea cucumber fishery would be related to the value of the species exploited.

In many cases throughout Micronesia local natural resource agencies lack the resources to effectively manage sea cucumber fisheries, and, as was the case of the Rota fishery, may even be unaware of its existence until it has already commenced, thereby eliminating any pre-harvest surveys that would allow rational harvest quotas to be set.

The only redeeming factor to arise from the Rota fishery was that, due to the regulations governing the CNMI DFW, any company desiring to export any marine product from the CNMI has to obtain an export permit from the DFW, to which data reporting conditions can be attached. Without such an option, it has become increasingly difficult to obtain harvest data.

In areas where no such laws exist, the situation becomes a relative impossibility. It is therefore in the best interests of natural resource agencies worldwide to assess their respective sea cucumber resources regardless of their harvest status. Assessment and establishment of rational harvest quotas ensures not only sustainable harvests, but also long-term biological sustainability of the species of economic importance.

In 1993, Richmond (1995) guided a workshop titled 'A Regional Management Plan for a Sustainable Sea Cucumber Fishery for Micronesia' at the University of Guam Marine Laboratory. The goals of the workshop were to develop a sea cucumber fishery management plan for Micronesia and to promote regional cooperation and coordination of research efforts. Although the difficulty of managing sea cucumber fisheries was illustrated in the Rota fishery, the guidelines generated by that workshop, as well as the support of numerous workshop participants, proved instrumental in obtaining the data summarised in this paper.

Acknowledgements

I would like to thank former Rota Division of Fish and Wildlife personnel Stan Taisacan and Steven Camacho for assisting in the data collection and fishery monitoring process. Former DFW Director Arnold Palacios provided logistical support, and Dr Robert Richmond of the University of Guam provided management guidelines and reference materials.

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Spawning and larval rearing of sea cucumber *Holothuria* (*Theelothuria*) *spinifera* Theel

P.S. Asha[1] and P. Muthiah[1]

Introduction

In India, the beche-de-mer industry mainly depends on *Holothuria scabra*, commonly called sandfish, a highly valued and widely distributed species. In addition to this, another species, *H. spinifera*, commonly known as brown sandfish, is also fished in large quantities and widely processed along the Gulf of Mannar and the Palk Bay, on the south-east coast of India. The animal is brown on the upper surface and lighter on the lower surface, with sharp projections all over the body (Fig. 1a). Being a highly burrowing species, it is found on clean sand in slightly deeper waters (James 2001). This species, locally called *Cheena attai* (or *Raja attai*), was once rated high in the market and was in good demand in China. At present, the market value is moderate, the freshly caught specimens are priced at Rs. 10–15/piece and the processed ones (Fig.1b) fetch Rs. 500–1000/kg depending on the size.

H. spinifera is fished throughout the year, usually by trawlers that form the major part of the sea cucumber fishery. It is also caught as a by-catch of *thallumadi*, a local fishing gear, and by skin diving during peak seasons. James et al. (1997) reported an estimated landing of 460 tonnes by a trawl net, modified to collect chanks locally known as *chanku madi,* during 1994–95 along the Rameswaram coast of the Palk Bay area. Sea cucumber caught in trawlers command a lesser price than those collected by skin diving, due to quality difference. Moreover, *H. spinifera* is very sensitive in nature and even a slight disturbance leads the animal to eviscerate, usually the gut along with the right respiratory tree and sometimes the gonad also. Hence, the specimens collected through skin diving were used as broodstock. Considering their commercial value, attempts were initiated for the hatchery production of seed. The hatchery technology for *H. scabra* has been developed by James et al. (1988). This paper presents the results of the

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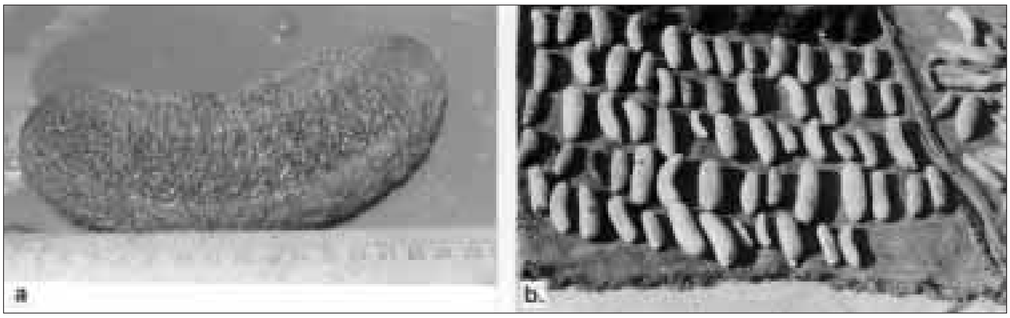

Figure 1. a. *Holothuria spinifera*, b. Processed product.

spawning and the subsequent larval rearing of *H. spinifera* in the laboratory conditions.

Material and methods

Broodstock

Eight *H. spinifera* (average length and weight 245 mm and 275 g) were collected from the wild, and maintained in the hatchery in a 1-tonne FRP tank containing six inches of coral sand. The water in the broodstock tank was changed daily and the sand every week. Animals were given an artificial feed made of four parts of rice bran, two of soya bean meal, and one of seaweed powder, at the rate of 5 g/day.

Spawning and larval rearing

Spawning was spontaneous, without any stimulation. After fertilisation, the eggs were washed to remove the excess sperm and the numbers estimated. The fertilised eggs were maintained at a rate of 0.5 larvae/ml in a 100-l tank with seawater filtered through a 40-µm sieve. The water in the larval rearing tank was changed completely and the larvae were taken out to find out the survival rate by counting the average numbers in three 1-ml samples on alternate days. Water was then changed at a rate of 50% per day, keeping the sieve (80 µm) inside the tank. This was followed up to 10 days and thereafter, a flow-through system was maintained. During the larval rearing period, the water temperature ranged between 29 and 31°C, salinity was 34.8–36.0 ppt, pH was 8.1–8.2, and the dissolved oxygen varied from 4.1–5.2 ml/l.

Feeding of the larvae

Feeding the auricularia larvae started from the second day onwards. A mixture of three microalgae, *Isochrysis galbana, Chaetoceros calcitrans* and *Nanochlorosis salina* (1:1:1), at the rate of 20,000 cells/ml, was given as initial feed, and slowly raised to 40,000 cells/ml in the later stages. After 10 days, once the larvae had reached the non-feeding doliolaria stage, the effectiveness of different settlement cues — like *Sargassum* powder, Algamac, *Spirulina* powder (0.05 g/l/day) and diatom, and dead algae (2 ml/l) — was tested using 2-l plastic bowls containing 5 doliolaria in filtered seawater.

Results

Spawning

On 2 March 2001, one of the males, after exhibiting the typical swaying movement, liberated sperm, as white threads, from the gonopore situated anteriorly. After the other animals were introduced to this sperm suspension, one of the females liberated eggs in a sudden spurt.

The eggs were spherical and visible to the naked eye, and their mean size was 143.59 ± 22.83 µm (Fig. 2a). The embryonic development was similar to that of *H. scabra*. Times after fertilisation for the different development stages are given in Table 1.

Table 1. Time after fertilisation for the different development stages of *Holothuria spinifera*.

Development stage	Time after fertilisation
Blastula	3 hours
Gastrula	24 hours
Auricularia (early)	2 days
Auricularia (late)	10 days
Doliolaria	10–12 days
Pentactula	13–15 days

The number of fertilised eggs was estimated as 60,000. The first polar body was released after 40 minutes and cleavage started in the next 20 minutes. Blastula, with a single blastopore, were observed after three hours. Motile gastrula (Fig. 2b) with ciliated and oval shaped bodies were developed in 24 hours with an average size of 265.40 ± 14.86 µm.

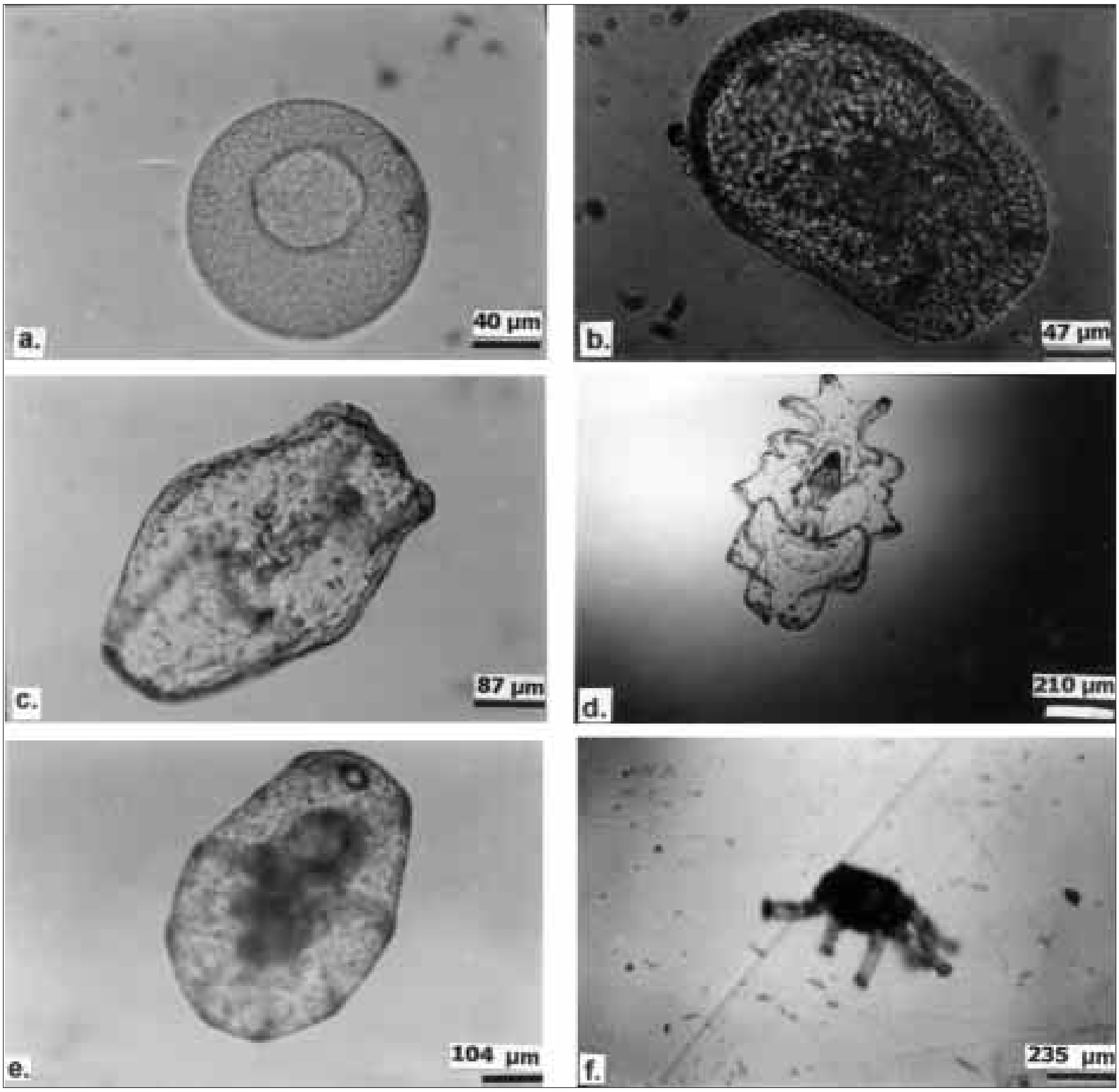

Figure 2. Larval stages of *Holothuria spinifera*:
a. Egg, b. Gastrula, c. Early auricularia, d. Late auricularia, e. Doliolaria, f. Pentactula.

The early auricularia were developed after 48 hours. They measured on average 498.43 ± 31.53 µm and were slipper shaped, transparent, and pelagic in habit, similar to those of *H. scabra*, except for the posterior loop, which was slightly broader than the anterior one (Fig. 2c). On the ninth day, lateral projections in the auricularia became more prominent, and lipid spheres appeared at the tips of the projections (Fig. 2d), which indicated the larval competency and its readiness to metamorphose in the congenial environmental condition (Battaglene 1999). At this stage it measured a mean size of 809.43 ± 123.29 µm, which is significantly different from the early auricularia ($t = 5.56$, $df = 11$, $P > 0.01$).

On the 10th day, a few auricularia were metamorphosed to the non-feeding, highly motile barrel-shaped doliolaria stage (Fig. 2e). The mean size was 467.57 ± 56.94 µm. A few doliolaria were metamorphosed to the creeping stage, called pentactula, on the 13th day. The composition of the larvae was observed to be auricularia 91%, doliolaria 8% and pentactula 1%. The pentactula were tubular with five tentacles at the anterior end and two podia at the posterior end (Fig. 2f). The colour was greenish brown and size was much smaller than that of *H. scabra*. The mean size at this stage was 330.16 ± 50.11 µm. By the 20th day, tube feet and tentacles became more distinct and spicules could be seen projecting from the skin of three specimens.

Survival to settlement

During the larval cycle, growth rate was progressive during 12 days, at a rate of 49.4 µm/day. The larval survival rate from the 4th to the 6th day remained at 76.9% and then decreased to 34.6% on the 11th day. The maximum mortality was noticed on the 9th day and also during the metamorphosis (Fig. 3). The larval settlement and further growth were affected greatly by the grazing of predators, which could not be controlled properly, forcing the experiment to be stopped.

The trial experiment conducted to test the effectiveness of different settlement cues indicated that the larval settlement can be better induced by Algamac and periphytic diatoms. Forty per cent survival was noticed in the larvae fed with Algamac, and 20% in those fed with periphytic diatoms. There was no settlement among the larvae fed with *Spirulina*, dead algae, or *Sargassum* powder (Fig. 4).

Discussion

The spawning of *H. spinifera* occurring without induction indicated a possible natural spawning period in March. Spawning in captivity has also been observed for *H. atra* (ICLARM Coastal Aquaculture Centre 1993). The sperm released might have induced the females to spawn. Battaglene (1999) has suggested that blended gonad from mature broodstock may be an effective spawning stimulant.

Fertilisation and early embryonic development up to late auricularia were similar to those of other holothuroids (Preston 1993). The time taken to reach the doliolaria stage is the same for *H. spinifera* and *H. scabra* (James et al. 1988) — 10 days. It is less than the 15 days taken by *Actinopyga echinites* (Chen and Chian 1990) and the 20 days taken by *H. atra* (Ramofafia et al. 1995).

Survival to settlement was 5%. Battaglene (1999) observed 1–35% mortality from survival to settlement and high mortality at first feeding and settlement. High mortality of 65.4% was noted on the ninth day, which was mainly due to ciliates.

As the larval and copepod sizes were similar, sieving out copepods was not possible. James et al. (1988) have observed similar hindrance of copepods in the larval rearing of *H. scabra*. Further studies have to be initiated to eradicate copepods in the larval rearing system.

In the settlement cue experiment, better settlement was observed among the larvae fed with Algamac (40%) and periphytic diatoms (20%). Similarly, Battaglene (1999) observed Algamac as a potential settlement cue and food for settled pentactulae of *H. scabra*. In future experiments, the feeding rates of suitable settlement cues will be given importance to enable large-scale seed production for ranching to replenish natural stocks of *H. spinifera*.

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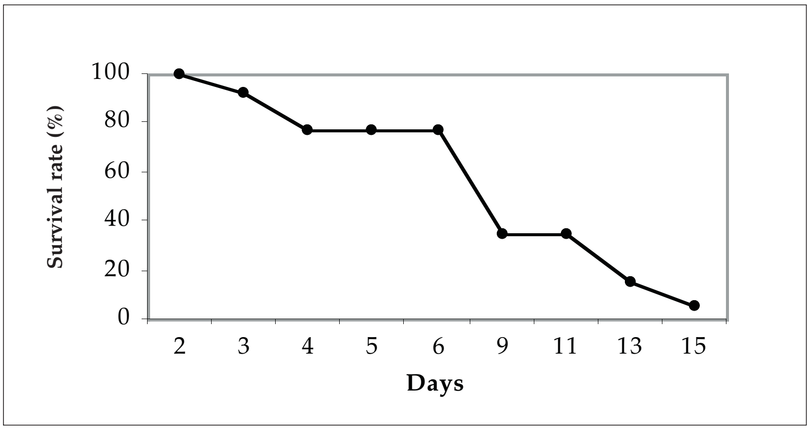

Figure 3. Survival of *H. spinifera* larvae.

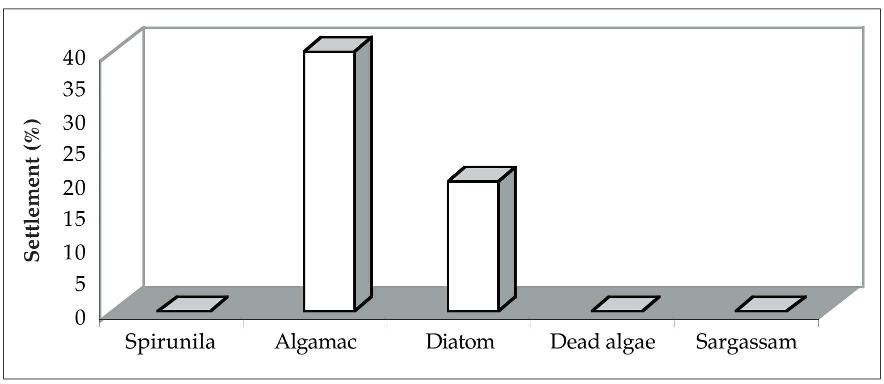

Figure 4. Settlement of *H. spinifera* larvae in different cues.

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Reactions of the larvae of the sea cucumber *Apostichopus japonicus* to sharp desalination of surface water: a laboratory study

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Introduction

Larval development of the sea cucumber *Apostichopus (=Stichopus) japonicus* Selenka to settlement occurs in the water column and lasts for 13–20 days depending on seawater temperature and salinity. Early larvae — blastula and gastrula — occur at the surface water, while later stages — dipleurula, auricularia and doliolaria — move into deeper water. Summer monsoon rains and floods of rivers flowing into Vostok Bay (Peter the Great Bay, the Sea of Japan) considerably reduce the salinity of the surface seawater, thereby affecting larval survival of *A. japonicus* (Kashenko 1992, 1997, 1998) and other invertebrates. Distribution, vertical migrations of marine bottom invertebrate larvae, and their behavioural responses to changing salinity in a stratified water column have been extensively studied. However, the conclusions made by the investigators are not unambiguous (Harder 1968; Mileikovsky 1974, 1981; Seliger et al. 1982; Mann 1986, 1988; Scheltema 1986; Stancyk and Feller 1986; Sulkin and Van Heukelem 1986; Tremblay and Sinclair 1990; Jonsson et al. 1991; Pedrotti and Fenaux 1992; Young 1995; Vazquez and Young 1996; Metaxas and Young 1998; Garrison 1999; Welch et al. 1999).

Reactions of the larvae of the sea cucumber *A. japonicus*, their behaviour, and vertical distribution caused by reduced salinity of surface seawater have not been studied. The aim of this research is a study of this problem under laboratory conditions.

Materials and methods

Experiments were carried out at the Vostok Marine Biological Station of the Institute of Marine Biology FEB RAS (Vostok Bay, the Sea of Japan) during July and August 1992.

Sea cucumbers in the pre-spawning state were collected on 15 July at 6 m of depth, at a temperature of 19.6°C and salinity of 32.7‰. Spawning proceeded on the same day, in separate vessels for females and males. Fertilisation, maintenance to settlement, and all experiments were carried out at a temperature of 22–23°C and salinity of 32‰ (Kashenko 1992). Larvae were reared in three larval cultures. Filtered and UV-sterilised seawater in aquaria was changed every 1–2 days. It was saturated with oxygen and stirred using a microcompressor that supplied air via glass capillaries to the water surface, inflicting no injury to the larvae.

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Early auricularias were fed with the small microalgae *Nannochloris maculata* and *Pavlova lutheri*, middle and late auricularias with the larger *Phaeodactylum tricornutum* and *Dunaliella salina*.

Responses, behaviour, and vertical distribution of *A. japonicus* in different larval stages (blastula, late gastrula, larvae in transition between gastrula and dipleurula, early auricularia, middle 10-day-old auricularia, late auricularia with hyaline spheres, doliolaria) were studied in relation to dilution of the surface layer of still sea water in the laboratory. One-litre graduated cylinders with a 6-cm diameter and 50-cm water column were used in the experiments. Surface water was diluted by slowly supplying water of reduced salinity to water of normal salinity (32‰) along the vessel's wall. The density gradient in the cylinders was not disturbed for more than one day, i.e., the water layer of markedly decreased salinity was hardly mixed with denser seawater.

Specific volumes of larval culture were emptied into control and experimental seawater cylinders at a depth of 19–20 cm before a diluted water layer was made. In each experiment, nearly the same larval densities were maintained in the cylinders. In some stages, larvae (30 individuals) were measured, and age from the time of fertilisation was estimated.

To model the situation occurring in the natural environment, the experiment was carried out in two variants. Variant I consisted of a sharp dilution. To the cylinder was added 25 ml of fresh water that was about 1 cm high. Variant II was a gradual dilution, with first 25 ml of 20‰ seawater and then 25 ml of 12‰ seawater added to the cylinder. The vessels were placed in front of a source of light. We used natural light but not direct sunlight coming from the window. This makes it possible to record the first response to dilution, follow behaviour, and count the number of larvae in the vessel, as well as to take samples of water from diluted layers that are clearly distinguishable visually.

For salinity determination and larval count, after 1 h of experiment, 0.3 mm of water was sampled using a Pasteur pipette with a thin long end to prevent the mixing of layers of different salinity. The water was sampled from different depths: at the surface film (0–0.2 cm and 0.2–1 cm), where there were no larval concentrations; 1–2 cm, where larvae most often concentrated; 2–3 cm, where larvae were few or absent; and then 3–4 cm, 6–7 cm, 18–19 cm, and deeper. In some cases, observations on the larvae and water samples were taken once every 3–4 h or once in a day. Salinity in micro-volumes of water was measured with an accuracy of 0.5‰ using a specially designed device (Tyurin 1994). Larvae were counted either in Bogorov's chamber or in graduated cylinders. Mean density of larvae (6 replicates: 3 larval cultures in each of 2 variants) were calculated. Salinity value at which larvae of a particular development stage concentrated were the same in experiment variants I and II, and larval densities in diluted horizons were also similar; therefore, the data in tables I and II were pooled. In control cylinders, larval densities at different depths were estimated to determine their normal vertical distribution. Analytic procedures followed Urbakh (1963). The hypothesis that treatments within an experiment were significantly different ($p \leq 0.05$) was satisfied in all experiments.

Results

In experiment variants I and II the width of diluted water layer where there were larval concentrations did not exceed 0.3–0.5 cm. In experimental vessels this horizon was usually at a depth of 1.0–1.5 cm.

In control cylinders, blastulas (at the age of 16 h, size 195 ± 24 µm) were constantly moving upward and downward. In the surface layer, their number was increased (Table 1). When water of the top layer was diluted to 9.5–13‰, blastulas accumulated in the horizon at 20–20.5‰. After being in contact with water of reduced salinity, larvae lost motility because of the osmotic shock and increased in size as a result of hydration; however, they rapidly recovered locomotor activity and survived for a long time in this layer but were not able to leave it (Table 1).

Table 1. Distribution of blastula larvae of *Apostichopus japonicus* in the water column one hour after dilution of the surface layer. Density data for variants I and II are pooled because the values are very similar. Mean larval densities (n = 6), 95% confidence intervals and mean values of salinities for variants I and II.

Depth (cm)	Larval density (nb./ml)		Salinity, ‰
	Control, salinity 32‰	Variants I and II	Variants I and II
0–0.2	7.50±1.12	0	–
0.2–1	3.33±0.64	0	5.5–14
1–1.4	0	34.6±6.91	20–20.5
2–3	0.10±0.01	0.08	30–31
3–4	0.12±0.01	0.08	32
6–7	0.12±0.01	0.08	32
18-19	0.34±0.04	0.08	32

– : not determined

A special experiment was carried out with late gastrulas (age 31 h) (Table 2). In the control, larvae at transition from gastrula to dipleurula were uniformly distributed in the water column, excluding the top 0–1 cm layer. Larvae in large groups were moving up and down. After the upper diluted water layer (6.5–17‰) had been formed, larvae began to stay in the horizon at 20–20.5‰. Disturbance of ciliary movements and hydration were observed in these larvae. After 1 h of experiment, their density in the layer was up to 17.4 ± 1.8 individuals per ml (Table 2). However, after 3 h, larvae already restored the normal work of cilia and began leaving the diluted horizon (Table 2). At the same time, the main mass of larvae in control cylinders descended to a depth below 10 cm and evenly spread in the water column. After 4 h, all larvae in experimental vessels left the diluted horizon. They were dipleurulas.

Auricularia is the sea cucumber's longest development stage; therefore, it was studied in detail. In the control, early auricularias (at the age of 61 h, size 538 ± 29 µm) were uniformly distributed in the water column, moving in large groups upward and downward but not entering the top 0–1 cm layer (Table 3). When surface water salinity was lowered to 5–15.5‰, larvae migrated deeper into the water column where salinity was 31–32‰ and did not come into reduced-salinity layers.

In control vessels, middle auricularias (at the age of 10 days, size 925 ± 43 µm) were uniformly distributed in the water column, slowly moving up and down and to and fro, not coming into the top layer (Table 3). Their number increased toward the bottom. At 4–15‰ in the top layer, auricularias concentrated in 20‰ water and after 1 h their den-

Table 2. Distribution of larvae of *Apostichopus japonicus* in the transition stage between gastrula and dipleurula in the water column 1, 3, and 4 h after dilution of the surface layer. Density data for variants I and II are pooled because the values are very similar. Mean larval densities (n = 6), 95% confidence intervals and mean values of salinities for variants I and II.

Depth (cm)	Larval density (nb./ml)					Salinity, ‰
	Control, salinity 32‰		Variants I and II			Variants I and II
	(in 1 h)	(in 4 h)	(in 1 h)	(in 3 h)	(in 4 h)	
0–0.2	0	0	0	0	0	–
0.2–1	0	0	0	0	0	6.5–17.0
1–1.3	0.82±0.14	0	17.4±0.18	16.5±0.24	0	20–20.5
2–3	0.60±0.12	0	0	0	0	27–26
3–4	0.40±0.08	0	0	0	0	32
6–7	0.50±0.10	0	0.10±0.02	0.16±0.04	0	32
12–13	0.50±0.07	1.00±0.13	0.24±0.06	0.90±0.12	1.58±0.31	32
18–19	0.50±0.00	1.20±0.18	0.97±0.11	1.00±0.14	1.72±0.38	32

– : not determined

Table 3. Distribution of early (age 61 h) and middle (age 10 d) auricularia larvae of *Apostichopus japonicus* in the water column one hour and one day after dilution of the surface layer. Density data for variants I and II are pooled because the values are very similar. Mean larval densities (n = 6), 95% confidence intervals and mean values of salinities for variants I and II.

Depth (cm)	Larval density (nb./ml)					Salinity, ‰	
	Control, salinity 32‰		Variants I and II			Variants I and II	
	(in 1 h) Early	(in 1 h) Middle	(in 1 h) Early	(in 1 h) Middle	(in 1 d) Middle	(in 1 h) Early	(in 1 h) Middle
0–0.2	0	0	0	0	0	–	–
0.2–1	0	0.22±0. 09	0	0	0	5–15.5	4–15
1–1.5	0.82±0.17	0.12±0.01	0	13.02±0.24	12.93±1.08	20–21	20
2–3	1.04±0.24	0.24±0.07	0	1.14±0.36	0.36±0.05	28–29	26–27
3–4	0.72±0.09	0.24±0.05	2.71±0.72	0.20±0.04	0.38±0.04	31–32	31–30
6–7	0.62±0.03	0.32±0.06	1.02±0.28	0.15±0.03	0.18±0.03	32	32
18–19	0.69±0.18	0.48±0.10	1.51±0.22	0.12±0.03	–	32	32

– : not determined

sity was 13.02 ± 1.76 individuals per ml. Larvae did not move because of the osmotic shock and were markedly hydrated. After one day, the vertical distribution pattern was somewhat different. Larvae that came into 20‰ water moved little, and at 25–26‰ some larvae left the layer.

In the control, late auricularias with hyaline spheres did not come into the surface layer (Table 4). Near the bottom their number increased. At 5–18.5‰ in the surface layer, larvae migrated to a depth of 18 cm where salinity was 32‰. Late auricularias were more motile and significantly decreased in size (763 ± 35 µm).

In the doliolaria, the main mass of control larvae remained near the bottom and only a small quantity of larvae approached the surface. They also actively migrated away from diluted surface layer (5–15‰) to a depth of 17–18 cm with normal salinity (Table 4).

Discussion

Most studies of the mechanisms of larval distribution in estuaries or in coastal waters have been performed on crustaceans, molluscs, and fishes. Larvae of different invertebrates respond to environmental changes in a different manner. In estuaries, larval transport is largely dependent on rapidly changing environmental factors, currents, and turbulence. The mechanisms and significance of larval transport cannot be separated from the overall biology of the organisms (Stancyk and Feller 1986). Dispersal of marine invertebrate larvae is related to the circulation of oceanic and estuarine water masses, as well as the length of development in plankton, age, and adaptability in each development stage. It has been suggested that either larvae are capable of active dispersal — that is, they control their spatial distribution in the water column (Mileikovsky 1974, 1981; Mann 1986, 1988; Scheltema 1986; Stancyk and Feller 1986; Jonsson et al. 1991; Young 1995; Vazquez and Young 1996; Metaxas and Young 1998; Welch et al. 1999) — or they are merely transported passively by currents or drifting in the estuarine systems (Seliger et al. 1982; Sulkin and Van Heukelem 1986; Garrison 1999).

The vertical distribution of the sea cucumber *Apostichopus japonicus* larvae in different development stages is known. Like other echinoderms (Rumrill 1989; Pedrotti and Fenaux, 1992; Metaxas and Young 1998), early larvae of *A. japonicus* occur in surface water, while late larvae migrate toward deeper horizons. There is no information on diel vertical migrations of larvae of sea cucumber in the natural environment. In this study, upward and downward migrations of larvae in control and experimental vessels are likely to reflect their behaviour in still water in the natural environment. At the same time, blastulas and gastrulas tended to occur near the surface layer, while later stages remained in the lower area of vessels.

In Vostok Bay, the surface water can be markedly freshened (1–10‰) by heavy rains, and in windless weather the stratified water column can persist for a long time (Kashenko 1997). In the morning hours, salinity of the surface water could lower to

Table 4. Distribution of larvae of the late auricularia with hyaline spheres and doliolaria of *Apostichopus japonicus* in the water column one hour after dilution of the surface layer. Density data for variants I and II are pooled because the values are very similar. Mean larval densities (n = 6), 95% confidence intervals and mean values of salinities for variants I and II.

Depth (cm)	Larval density (nb./ml)				Salinity, ‰	
	Control, salinity 32‰		Variants I and II		Variants I and II	
	Late auricularia	Doliolaria	Late auricularia	Doliolaria	Late auricularia	Doliolaria
0–0.2	0	0	0	0	–	–
0.2–1	0	0	0	0	5–18.5	5–15
1–2	0.18±0.05	0	0	0	23–25	25–26
2–3	0.24±0.04	0	0	0	31	31–31.5
3–4	–	0.01	0	0	32	32
6–7	0.28±0.04	0.04±0.01	0	0	32	32
18–19	0.36±0.06	150	0.27± 0.07	0.04±0.01	32	32
25–26	0.32±0.05	0.08±0.02	0.53±0.09	0.08±0.01	32	32
36–37	0.78±0.06	0.76±0.12	0.89±0.16	0.98±0.04	32	32

24–27‰ in calm weather. It is at this time that newly hatched blastulas of sea cucumber ascend by moving their cilia to the water surface; adult sea cucumbers, as suggested by our observations, spawn either late in the evening or around midnight. Meeting with the diluted horizon, blastulas stopped moving upward at salinity causing the osmotic shock. The larvae soon adapted to 20‰ and began swimming but were still unable to leave the diluted horizon because they became less dense in the iso-osmotic environment, as indicated by their enlarged size (hydration), and could not overcome the density gradient to penetrate into the underlying horizon where density was higher. Blastulas and gastrulas can descend only when they stop the work of cilia on their bodies.

Like blastulas, gastrulas have no locomotor organ and hence were also unable to leave the diluted horizon. Previous studies showed that if the blastula and gastrula stages were exposed to reduced salinity (20‰), larvae in the subsequent stages became more resistant to decreased salinity (Kashenko 2000). An experiment with larvae transiting from gastrula to dipleurula showed that some larval stages can actively respond to reduced salinity. In the dipleurula of sea cucumber, the nervous system is laid down (Dautov et al. 1991) and the larval locomotor organ, a ciliary band, appears. Therefore, dipleurulas were probably able to leave the reduced salinity horizon. Thus, after the nervous system and larval locomotor organ have been formed, larvae began to actively respond to unfavourable conditions, in particular to the change in salinity.

In the 20‰ horizon, there were also middle auricularias. It has been shown that at 22–24‰ of the locomotor activity in the auricularia can be recovered in 2.5 days. Larvae in this stage are more vulnerable and perish at 20‰ (Kashenko 1992). Moreover, middle auricularias have by far greater size and more complex body shape, compared to other larvae. This probably does not allow them to rapidly react to sharp changes in the environment. Scheltema (1986) noted that at a change of the environmental conditions 'the response of a bipinnaria or polychaete larva will therefore necessarily differ from that a bivalve or decapod larva.'

Our studies showed that early auricularias, late auricularias with hyaline spheres, and doliolarias are able to respond to environmental signals and avoid decreased salinity in non-turbulent water. Thus, early larval stages of sea cucumber cannot actively avoid adverse environmental conditions, while later larvae exhibit preferential response to salinity changes.

Harder (1968), who studied planktonic organisms, found that most plankters stopped moving at the freshwater-seawater interface. This response by plankters was associated with markedly different characteristics of density in these layers. A similar response was reported for larvae of three mactrid bivalves and it was attributed to differential behaviour along the salinity gradient (Mann et al. 1991). In the stratified water column sea scallop larvae *Placopecten magellanicus* showed subsurface peaks in concentration above the pycnocline (Tremblay and Sinclair 1990). Pedrotti and Fenaux (1992) also remarked that the stratification of the water column keeps larval distribution of echinoderms near the surface waters. Chinese investigators (Zhenzu and Wenxiong 1993) suggested that salinity stratification in natural environments greatly influences vertical migrations of larval oysters *Crassostrea gigas*. Metaxas and Young (1998) also showed that larvae of sea urchins crossing a halocline encountered water of lower salinity that might induce osmotic stress. From the above, it can be concluded that the stratification of the water column in estuaries and bays leads to the accumulation of marine invertebrate larvae in waters of reduced salinities, causing osmotic shock and loss of locomotor activity in the larvae. Depending on age and adaptability, larvae either will be able to leave waters of reduced salinity or will stay there. It can be assumed that this is one of the reasons why larvae are retained in the near surface water or above or below the pycnocline.

Conclusions

At desalination of surface water, larvae of *A. japonicus* in the blastula, gastrula, dipleurula, and auricularia stages lost motility and accumulated in those horizons where seawater salinity caused an osmotic shock. Blastulas and gastrulas concentrated at 20–20.5‰. Although blastulas were not able to leave this horizon, they survived in it. Larvae that developed from gastrula to dipleurula in the diluted water horizon left it. Middle auricularias were not able to leave the 20‰ water horizon and perished. At dilution of surface water, early and late auricularias and doliolarias migrated into deeper water of normal salinity. Thus, adaptive plasticity and behavioural mechanisms allow larvae in some stages of the sea cucumber *A. japonicus* to survive and avoid the adverse effects of reduced salinity in surface layers of seawater.

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market news beche-de-mer

Beche-de-mer prices on the Asian markets (August 2001 to April 2002)

Species	Size		Indicative price in US$/kg (C&F) Aug. 2001 – Apr. 2002									Market area	Origin
			Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.		
White teatfish (skin-on)	3–5 pc/kg	A	25.0	23.0	24.0	23.0	21.0	21.0	23.0	23.0	23.0	SE Asian ports	S. Pacific
		B	18.0	16.0	16.0	16.0	13.0	13.0	13.0	13.0	13.0	SE Asian ports	S. Pacific
Prickly Redfish *(Thelenota ananas)*	6-15 pc/kg		12.0	10.0	10.0	10.0	10.0	10.0	12.0	12.0	12.0	SE Asian ports	S. Pacific
Black teatfish	3-5 pc/kg	A	18.0	17.0	17.0	15.0	15.0	15.0	18.0	18.0	18.0	SE Asian ports	Australia
		B	15.0	14.0	14.0	13.0	12.0	12.0	12.0	12.0	12.0	SE Asian ports	Australia
Sandfish		A	33.0	30.0	32.0	32.0	32.0	32.0	34.0	34.0	34.0	Singapore	Indonesia
	10-30 pc/kg		58.0	50.0	50.0	45.0	43.0	45.0	45.0	45.0	45.0	Singapore	Australia
	15-40 pc/kg		40.0	35.0	35.0	35.0	35.0	35.0	40.0	40.0	40.0	Singapore	S. Pacific
Greenfish *(Stichopus chloronotus)*	50-120 pc/kg		10.0	10.0	10.0	10.0	10.0	10.0	13.0	13.0	13.0	Singapore	S. Pacific
Lollyfish			2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	Singapore	S. Pacific
Stonefish			15.0	14.0	15.0	15.0	15.0	12.0	14.0	14.0	14.0	Singapore	Indonesia
Surf redfish *(Actinopyga mauritiana)*	15-35 pc/kg		12.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	Singapore	S. Pacific
Tigerfish	25-55 pc/kg		3.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	Singapore	S. Pacific
Brown sandfish *(Boadschia marmorata)*	25-110 pc/kg		3.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	Singapore	S. Pacific
Curryfish *(Stichopus variegatus)*	30-50 pc/kg		17.0	15.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	Singapore	S. Pacific
	70-120 pc/kg		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	Singapore	S. Pacific
Elephant trunkfish	3-8 pc/kg		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	Singapore	S. Pacific

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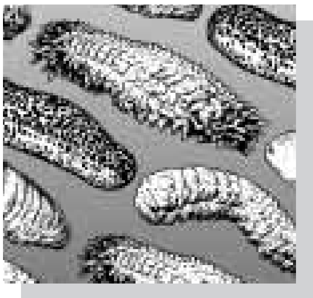

abstracts, publications, workshops & meetings
beche-de-mer

Abstracts from communications presented at the 6th European Congress on Echinoderms, Banyuls, France, September 2001

The endosymbiotic turbellarians infesting *Holothuria tubulosa* at Banyuls-sur-mer (France)

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Holothuria tubulosa is infested by two species of Umagillidae (Platyhelminthes): *Anoplodium parasita* and *Anoplodium* n. sp. The first species lives in the coelom. Twenty-six holothuroids out of 202 collected were infested by one to six *A. parasita*. The infestation is uniform throughout the year but the number of egg capsules found in the coelom as well as the number of holothuroids infested by egg capsules fall drastically in July. *Anoplodium* n. sp. inhabits the digestive lumen. The infestation by *Anoplodium* n. sp. is higher than that of *A. parasita* but is constant whatever the sampling period: 67 holothuroids out of the 202 investigated were infested by one to eight *Anoplodium* n. sp. No egg capsule was found in the digestive lumen of holothuroids.

Our study strongly suggests that the success of the infestation of the first species depends on the reproductive mechanism of holothuroids. For both flatworms, the infesting stage is the egg capsule that is ingested when the host is feeding. Hatching would occur in the intestine. *Anoplodium* n. sp. grows and reproduces in the digestive tract, producing egg capsules evacuated with the host faeces, while juveniles of *A. parasita* would actively pierce the digestive epithelium to grow then reproduce in the coelomic cavity. There, egg capsules accumulate until the discharge of the host gametes, which occurs in summer. It is suggested that during this period, the host body contracts strongly and purges all its coelomic contents through coelo-rectal ducts.

Reproduction and protected development in *Psolus patagonicus* (Holothuroidea) from Argentina

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Psolus patagonicus (Ekman 1925) is an abundant holothuroid, living on a variety of habitats and substrata; it has been recorded in the intertidal rocky shores and on *Macrocystis pyrifera* fronds and holdfasts of southern Patagonia and together with live scallops (*Zygochlamys patagonicus*). We took monthly samples from October 1999 to March 2001 of *Psolus patagonicus*, from the *Zygochlamys patagonicus* fisheries, operating around 39°26'S 55°56'W at 100–110 m depths. Each month, about 50 specimens were fixed in formol (5%) for later microcopical studies of the gonads. *Psolus patagonicus* incubates the eggs and embryos under the sole; the complete development process takes seven months. The smallest recorded incubating female was 17 mm in length and the maximum size recorded was 23 mm. The setting of the eggs under the sole is realised in February and March (uncleaved egg diameter: 887.72 ± SD 26.71 µm), with an average of 147± SD 20 eggs per brooding female; the embryos develop when they reach a size of 1972.57 ± 158.22 µm in September, with 82 ± SD 14 embryos per female. Independent life is achieved in October at a size of 2220 ± SD 210 µm.

The origin of holothurians in Procrustes' bed of embryology and palaeobiology

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Interpretation of the origin of holothurians is controversial. Recent results from molecular data and cladistics (Littlewood et al. 1997, Biol. J. Linn. Soc. [61]:409–438) may support earlier hypotheses of a nearer echinoid-holothurian relationship; on the other hand, by reference to apparent non-homologies, e.g. of radial canals (Smiley 1986, Biol. Bull. [171]:611–631; David and Mooi, e.g. 1998, In: Echinoderms, San Francisco: Balkema, 21–28) one would see greater phylogenetic distances between these echinoderm groups. In the model presented here, the origin of holothurians is explained by arguments of constructional morphology. According to this, structures of special interest in a blueprint are related to physical constraints and limitations in a forerunner construction. In a feasible step-by-step reconstruction of transitional stages, reasons for reduction of skeletisation, elongation of the body, non-development of a chewing apparatus and origin of hind part coelomic structures are explained as constructional improvements in relation to new functional demands. The database used for corroboration, e.g. 'known anatomy and embryology of Recent holothurians,' is enlarged by Devonian fossils reflecting the position of hydrocoelic structures behind the calcareous ring.

Temporal variation of gonad morphology and gametogenesis of the commercial sea cucumber *Isostichopus badionotus* from south-east Brazil

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Samples of *Isostichopus badionotus* (Selenka 1867), a sea cucumber commonly encountered on the southern coast of Rio de Janeiro, were collected monthly from Ilha Grande Bay. Organ indices were calculated on the basis of the relationship between organ and total body wet weight. The gonad index was highest in late spring (end of October until mid-January). The numerous tubules of the gonad varied greatly in size and colour throughout the reproductive cycle. Gonads were prepared for histological examination and then stained with haematoxylin and eosin. The gonadal development was classified into five stages: recovering, growing, mature, partly spawned, and spent. Diameter of the gonadal tubules was measured, and oocyte size frequency calculated. The mature stages had the largest gonad tubule diameter (1.0 mm). Spent gonads had tubules of 0.18 mm diameter. Different stages of gametogenesis produced significant changes in the morphology of the gonad tubules. The highest mean oocyte size was 140 µm. This corresponded to the highest gonad index (3.72 ± 1.68). The gonad index decreased gradually through the summer and early autumn months, possibly indicating that *I. badionotus* spawns in the summer when water temperature is highest (± 30° C). The relevance of gametogenesis for the establishment of sustainable utilisation of *I. badionotus* as a food source is discussed, as this species is commercially exploited and consumed by sectors of the Asian and European communities in the city of Rio.

Abundance, dispersion and microdistribution of aspidochirotid holothurians (Holothuroidea: Echinodermata) in the *Posidonia oceanica* meadow of the Sidi Fredj peninsula (Algeria)

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The deposit feeders aspidochirotid holothurians, commonly known as sea cucumbers, represent the major component of the *Posidonia oceanica* benthic ecosystem in the Mediterranean Sea. They participate actively in the recycling of organic matter by ingesting the sediment layer and/or the bottom wreck. The particular biota and the sciaphilous behaviour of these animals make them particularly difficult to sample, restricting the possibility of the study of their distribution in the *Posidonia oceanica* meadow. In addition, few data on the factors influencing their distribution are available.

The present study deals with four aspidochirotid holothurians species — *Holothuria tubulosa* Gmelin 1788, *H. polii* Delle Chieje 1823, *H. sanctori* Delle Chieje 1823, and *H. forskali* Delle Chieje 1823 — found in a small shallow-water area (500 m^2, 0.5–3 m depth) of *Posidonia oceanica* meadow of the Sidi Fredj peninsula, situated 20 km west of Algiers. The sampling was done underwater by means of scuba-diving and consisted of counting individuals of each species using the Quadra method. To study the dispersion of each species, a relationship between the variance and the mean value of the monthly densities was established. To locate each holothurian species in the *Posidonia oceanica* meadow, we defined four biota ('herbier sur matte' (seagrass bed), 'tombant de matte' (slope of seagrass bed), 'intermatte' (interval between seagrass beds), and 'melange de blocs' (blocs mixtures)) in the studied area. The mean densities and the corresponding percentages have been evaluated on a surface corresponding to 19 quadras (1 m x 1 m each) for each biota, during one cycle (from March 1995 to February 1996).

The established census revealed a net dominance of *H.* and *H. polii*. The studied species dispersion was random to quiet aggregate. This situation was governed mainly by the feeding behaviour of these deposit-feeding species and by the essential ecological factors, especially food availability, hydrodynamism, and light. The micro-distribution was clearly different from one species to another, with *H. tubulosa* showing a preference for the sea grass (herbier) and blocs mixtures (mélange de blocs) biota, whereas *Holothuria polii* confine themselves in the 'inter-mattes.' *Holothuria forskali* were found mainly in 'inter-mattes' or 'tombant de mattes,' together with *H. sanctori*.

Systematic revision of five aspidochirote holothurians species (Holothuroidea: Echinodermata) inhabiting the *Posidonia oceanica* meadow of the Sidi-Fredj peninsula (Algeria)

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In this study, we tried to overview the systematics of five Mediterranean aspidochirote holothurian species. Following a morphological, endoskeletal, and anatomical study, and using the most recent systematic works, we could identify two species groups: 1) *Holothuria (Holothuria) tubulosa* Gmelin, *H. (H.) stellati* Delle Chieje, and *H. (Lessonothuria) polii* Delle Chieje were characterised by very diversified spicules in form and in size. 2) *H. (Panningothuria) forskali* Delle Chieje and *H. (Platyperona) sanctori* Delle Chieje differ from members of the first group by the extreme reduction of their spicules in number and in size. *H. (H.) tubulosa* and *H. (H.) stellati* are often confused because of the similarity of their external morphology. However, *H. (H.) stellati* differs from *H. (H.) tubulosa*, from the endoskeleton point of view, by its large thick sticks that present side ramifications of complex forms. *H. (Platyperona) sanctori* is recognised morphologically by the white spots located on its dorsal face, while *H. (Panningothuria) forskali* presents two morphological types: one being soft and brown and the other black.

Fossil calcareous ring elements of Holothuroidea

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Fossils of sea cucumbers are mostly known from calcareous sclerites (ossicles) of the body wall. Elements of the pharyngeal ring can, however, also occur as fossils. The calcareous ring (c.r.) consists mostly of five radial and five interradial plates or elements, sometimes forming a variable mosaic of several elements, with sizes varying between 0.3 and 5 mm. The morphology of the rings and pieces is significant for the differentiation of Recent Holothuroidea families and orders. Since complete c.r. are very rare in the fossil record, isolated pieces of the c.r. are very helpful for the reconstruction of evolution and phylogeny of Holothuroidea. The present study emphasises the possibility that pieces of the c.r. may occur in marine sediments. The investigations of the author show that isolated pieces are, in fact, very common in the mesofauna (fraction size 0.5 to 10 mm).

Previous papers dealing with this subject are mostly lacking descriptions and/or designations of the specific elements. The reasons for this are: 1) lack of figures and/or descriptions of morphotypes in nearly all palaeontological textbooks; and 2) the fact that a comprehensive study of the '3-D' morphology of Recent c.r. (and elements) is not available. The interpretation of fossil material is thus often difficult or impossible. The Radials and Interradials from the Upper Permian of Germany and England are, for example, misinterpreted as 'fused side shields' or 'deformed side shields' of ophiuroids (Malzahn 1957, Pattison 1984).

Nearly complete c.r. are commonly known from Devonian (Lehmann 1958, Seilacher 1961) and Triassic (Smith & Gallemí 1991, Hagdorn 1993) sediments. A single example of a complete c.r. is reported from Carboniferous (Sroka 1988), Jurassic (Hess 1973), and Upper Cretaceous (Hückel 1970, Reich in prep.) sediments. Findings of c.r., or pieces of the c.r., from Cenozoic sediments are unknown.

Isolated findings of Mesozoic c.r. elements are known mostly from Jurassic (e.g. Hess 1975; Gilliland 1992), rarely from Triassic (Kristan-Tollmann et al. 1991) and Cretaceous sediments (Reich 1997). The oldest elements of the c.r. originate from the Llanvirnian of Baltoscandia (Reich 2000) and the Silurian (Ludlovian) of Gotland (Reich 1999). Devonian forms are sometimes reported (Haude 1983). Proofs of these elements from Cenozoic sediments are again hitherto unknown.

Holothurians from the Toarcian of western France

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Until now, almost all fossil holothurians from France date from the Upper Jurassic and the Tertiary (e.g. works of Deflandre-Rigaud, Valensi, Guyader). Remains of holothurians from the Early Jurassic were first figured by Terquem and Berthelin (1875). Next, the works of Rioult provided a parataxonomic and biostratigraphic framework for the Early Jurassic holothurians of the Paris basin.

During new investigations nearly 1000 holothurian sclerites and elements of the calcareous ring have been isolated from sediment samples from the Seuil du Poitou (the stratotypical section of the Toarcian at Thouars, as well as the Sanxay and Montalembert quarries). Up to now, we have been able to recognise nine species (paraspecies and sclerite associations) of Holothuroidea, representing the orders Aspidochirotida Grube, Apodida Brandt, and Dendrochirotida Grube. Aspidochirotid (*Priscopedatus* spp.), synaptid (juvenile wheels: *Theelia* spp.), and myriotrochid (radials and interradials) holothurians, respectively, proved to be the most abundant groups in all samples studied. Some of these species are known also from the Jurassic of Germany and the United Kingdom. Thus, in the Toarcian of the Seuil du Poitou, epibenthic and endobenthic deposit-feeders like Aspidochirotida and Apodida seem to predominate. Suspension feeders are found less frequently.

Processing *Holothuria scabra* for the trade

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Demersal life of *Holothuria scabra* and its morphological characteristics are manifested in the methodology used to process it for the trade. As with most holothurians, removal of the external coating of the skin and the entrails forms the essence of the method of *H. scabra* processing. Removing the entrails through induced evisceration, boiling to ensure uniform contraction of the musculature, and cleaning the external coating of the skin before final drying are the steps that ensure efficient preservation of the musculature. Each step is supported by a carefully thought-out technique appropriate for the rural condition of the fishermen in most countries of the Indo/Pacific region, from where large quantities of the processed product are exported to the markets in South-East Asia. This paper details the steps used in the processing method, describing the need for the adoption of the technique involved in each step, and explaining the consequences of the methodology, which matches the characteristics of the holothurian to the market requirements.

Echinoderms investigations in Russian Far East

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The Pacific Research Fisheries Center (TINRO-Center) is the leading scientific institution investigating echinoderms in Russia's Far Eastern seas. All the investigations are determined by the species' commercial value. The stocks of sea urchins have been assessed at 150,000 t and stocks of holothurians at 67,500 t. Sea urchins (*Strongylocentrotus intermedius*, *S. nudus*, and *S. droebachiensis)* and cucumaria (*Cucumaria japonica)* form the basis of a commercial harvest in the Japan Sea, the Okhotsk Sea, and the Bering Sea. In connection with it, research focuses on the biology, reserves, distribution, age and size structure, and conditions of forming accumulations of these species of echinoderms, and their peculiarities in reproduction. Detailed information is collected on sea urchin reserves, their reproductive indexes, and bottom types and algae cover. This allows measures to be developed to increase sea urchin reserves in the region.

We also investigate the relations between phytocenosis composition and the pigment composition of sea urchin gonads, as gonad colour is one of their important characteristics. In addition, we study the deep sea urchin *Strongylocentrotus pallidus*, which is not commercially exploited yet, and the sand dollar *Echinarachnius parma*. Lately, stock depletion of some species of echinoderms has been observed. Working out aquaculture methods for the sea cucumber *Stichopus japonicus* and for sea urchins becomes an important goal. Research on the chemical composition of organs and tissues of sea urchins and cucumaria, to create medical-prophylactic biopreparations, are on hold.

Towards an understanding of the shallow-water echinoderm biodiversity of KwaZulu-Natal, Republic of South Africa

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Prior to this study, 130 shallow-water (i.e. less than 50-m deep) species of echinoderms were reported from the subtropical (26°S/32°E – 30°S/30°E) east coast of South Africa. The Indo-Pacific and the endemic components of this fauna made up 93 % of the species, while the circumtropical, the Atlantic and the cosmopolitan components represented only 7 % of the echinoderm fauna. A current study in the KwaZulu-Natal province has added some 39 % of new records (excluding the Crinoidea) to the echinoderm fauna of this province, changing its endemic component from 26 to 21 % and its Indo-Pacific component from 68 to 73 %, with the other components remaining more or less stable. The total echinoderm species distribution of KwaZulu-Natal was analysed with the second Kulczynski coefficient, a measurement of similarity between two bioassociational areas. This analysis reveals that while the faunistic components of KwaZulu-Natal seem rather homogeneous, the area in the region of St. Lucia Bay appears to be characterised by a high species turn-over.

Other Abstracts

Some aspects of sea cucumber *Holothuria scabra* along the coast of Dar es Salaam

T. Kithakeni

Source: Second WIOMSA Scientific Symposium, October 2001, Dar es Salaam, Tanzania

Sea cucumbers have a long history of exploitation in East Africa. However, the work by Frontier-Tanzania on Mafia Island, Songo Songo, and Mtwara has shown that catches have fallen drastically over the last few years. Since sea cucumbers are slow growing, populations in shallow water are easily overexploited; and the average size of animals has become much smaller as the larger animals are taken first, since the trade is not regulated. The foreign earnings from sea cucumbers show an increase from USD 442,335 in 1988 to USD 884,169 in 1994. However, since 1995 there has been a decrease in catch in Tanzania (Fisheries Division of the Ministry of Natural Resources and Tourism 1996). Some aspects of the biology of *Holothuria scabra* have been studied along the coast of Dar es Salaam. Samples of *H. scabra* were collected from Kunduchi and Buyuni between January and December 1999. Comparison of abundance of *H. scabra* between the two sites showed higher density in Buyuni than in Kunduchi. However, total collection at the landing sites — that is, level of exploitation per year — from far reefs was higher in Buyuni (3951) than in Kunduchi (1176). Exploitation is done every month on intertidal areas and from reef flats near the villages. Higher catches from Buyuni were recorded during August and November, perhaps due to light winds allowing trips to be made to far reefs, while the catch from Kunduchi was relatively low throughout the year. The local markets are mostly not open and are poorly organised and not easily accessible. Products are of low quality and size and prices are unregulated. The length–frequency distribution of *H. scabra* was found to be unimodal, with most individuals of 17.5 cm. The species was shown to have a continuous breeding season with peaks in September and December. Its average size at first maturity was found to be 16.8 cm.

Population genetics of the fissiparous holothurians *Stichopus chloronotus* and *Holothuria atra* (Aspidochirotida): a comparison between the Torres Strait and La Réunion

S. Uthicke, C. Conand and J.A.H. Benzie

Source: *Marine Biology* (2001) 139:257–265

Collections of about 50 individuals from each of five populations of the fissiparous holothurian species *Stichopus chloronotus* and four populations of *Holothuria atra* were made in 1999. These populations were located in the Torres Strait (western Pacific) and at La Réunion (western Indian Ocean). Allozyme electrophoretic surveys of five (*S. chloronotus*) and six (*H. atra*) loci were conducted to compare patterns of asexual reproduction and to investigate connectivity between regions separated by large geographic distances. Deviations from genotype frequencies expected under Hardy-Weinberg equilibrium, mostly heterozygote excesses, were observed in all populations of both species. The maximum contribution of sexual reproduction (calculated as the maximum number of sexually produced individuals: sample size = N* Ni) was similar for all *S. chloronotus* (58–64%) and *H. atra* (76–92%) populations, and on the same level as previously

reported for midshelf reefs of the Great Barrier Reef. The higher values in the latter species indicated greater contributions of asexual reproduction to *S. chloronotus* populations. Variability was strongly reduced in *S. chloronotus* populations at La Réunion, with only one locus being variable in that population. When the dataset was reduced to one representative per multilocus genotype per population to reduce the effect of asexual reproduction on calculations on gene flow, Fst values were not significantly different from zero, suggesting high gene flow between these regions. However, UPGMA cluster analyses, using Roger's genetic distance, roughly clustered populations by region. In the case of *H. atra*, pooled populations within each region were significantly different from those of the other region. Thus, although some restrictions in gene flow and greater genetic distances between the regions may exist, those differences are distinctly less than those reported in previous studies on echinoderms over similar geographic scales. Despite the importance of asexual reproduction for the maintenance of local population size, this study also confirmed that the potential for widespread dispersal mediated by sexually produced larvae is large.

A new species of *Holothuria* (Aspidochirotida, Holothuriidae) from Kenya

Y. Samyn, C. Massin and N.A. Muthiga

Source: Annls Mus R. Afr. Centr. (Zool.) (2001) 285:101–110.

A new species, *Holothuria (Mertensiothuria) arenacava* (Echinodermata, Holothuroidea), from the littoral waters of Kenya, is described. This species is characterised by its sand-burrowing behaviour; its small tentacles; the variously developed tables, corpuscules, buttons, plates, and rods in the tube feet; and by the smooth, spiny, and knobbed rods in the tentacles.

Effect of beche-de-mer fishing on densities and size structure of *Holothuria nobilis* (Echinodermata: Holothuroidea) populations on the Great Barrier Reef

S. Uthicke and J.A.H. Benzie

Source: *Coral Reefs* (2000) 19:271–276

Decreasing catch rates for *Holothuria nobilis* (black teatfish) on the Great Barrier Reef (GBR) prompted management agencies to close the fishery for this species in October 1999. At the same time, we surveyed densities and size structure of *H. nobilis* populations in the main area fished on the GBR. Densities of *H. nobilis* on four reefs protected from fishing (approximately 20 individuals per ha) were about four times higher than those on the 16 reefs open to fishing (approximately 5 individuals per ha). Each of four other reefs had been divided into an area protected from fishing and an open area. On the largest of these reefs (ca. 28 km long), densities of *H. nobilis* were nearly five times higher in the protected area compared to the area open to fishing. On three smaller reefs (<11 km long), however, densities were not significantly different between the open and protected areas, and were similar to those on reefs completely open to fishing. The average weight of individuals was reduced on fished reefs (1763 g) compared to closed reefs (2200 g). Thus, beche-de-mer fishing led to a strong reduction of density and biomass of *H. nobilis*. The division of smaller reefs into open and closed zones appears not to provide sufficient protection, but reefs that are completely closed to fishing appear to provide some degree of protection. There were some indications that proximity to tourist attractions may enhance the effect of protection.

Restricted gene flow between *Holothuria scabra* (Echinodermata: Holothuroidea) populations along the north-east coast of Australia and the Solomon Islands

S. Uthicke and J.A.H. Benzie

Source: *Marine Ecology Progress Series* (2001) 216:109–117

To describe patterns of gene flow for the fished holothurian species *Holothuria scabra*, 17 to 141 individuals were collected from eight populations from north-east Australia, the Torres Strait, and Solomon Islands. Samples were investigated by allozyme electrophoresis of seven polymorphic loci. Cluster analyses using Rogers' genetic distance identified three distinct groups of populations from the north-east coast of Australia, representing samples from the three regions: Hervey Bay, Upstart Bay, and Torres Strait. Populations in the latter region were closely connected to those from Solomon Islands. F-statistics indicated restrictions in gene flow (average genetic variation between populations Fst = 0.088). Hierarchical analyses revealed that 94.7% of the variation was within sampling locations. Approximately 77% of the variance among populations was due to differences between regions, and 23% within regions (most of the latter caused by differences between the two Solomon Islands populations). Mantel's tests indicated that a high proportion of the variation in genetic distances along the north-east coast of Australia was explained by isolation by distance (Mantel's normalised $Z = 0.88$). This proportion reduced when Solomon Islands was included ($Z = 0.65$). The detection of separate stocks along the north-east coast of Australia is an important finding that has significant consequences for the development of sustainable management plans for this species. Low dispersal may significantly reduce recovery of overfished areas if no local refugia are provided.

The use of marine reserves in evaluating the dive fishery for the warty sea cucumber (*Parastichopus parvimensis*) in California, USA

Stephen C. Schroeter, Daniel C. Reed, David J. Kushner, James A. Estes and David S. Ono

Source: *Can. J. Fish. Aquat. Sci.* (2001) 58:1773–1781

Management of sustainable fisheries depends upon reliable estimates of stock assessment. Assessment of many stocks is based entirely on fishery-dependent data (e.g. catch per unit effort), which can be problematic. Here we use fishery-independent data on stock size, collected within and outside of no-take reserves before and after the onset of fishing, to evaluate the status of the dive fishery for warty sea cucumbers, *Parastichopus parvimensis*, in southern California. Long-term monitoring data showed that abundance decreased throughout the Channel Islands within 3–6 years after the onset of fishing. No significant changes in the abundance of *P. parvimensis* were observed at the two non-fished reserve sites, although densities tended to increase following onset of the fishery. Before-after, control-impact (BACI) analyses of seven fished and two non-fished sites implicated fishing mortality as the cause of 33–83% stock declines. In sharp contrast, stock assessment based on CPUE data showed no declines and a significant increase at one island. To date, most discussion on marine reserves has focused on the protection and enhancement of exploited populations. Our study demonstrates the critically important, but often overlooked, role that marine reserves can play in providing reliable information on stock assessment.

Biodiversity of seaweeds and echinoderms in the western Indian Ocean

J.J. Bolton, E. Coppejans, R.J. Anderson, O. De Clerck, Y. Samyn, F. Leliaert and A.S. Thandar

Source: *South African Journal of Science* 97(11/12):453–454..

Meetings

Echinoderms 2000 proceedings

The Proceedings of the 10th International Conference on Echinoderms held in Dunedin are now available: M. Barker, ed. 2001. Echinoderms 2000. Lisse, The Netherlands: Balkema/Swets & Zeitlinger. 590 p.

Echinoderms 2003

The 11th International Echinoderm Conference will be held at the Ludwig-Maximilians-Universität, Munich, Germany, from 6 to 10 October 2003. Registration and abstracts as well as special requests, comments and proposals should all be sent to T. Heinzeller — if possible by e-mail to Heinzeller@anat.med.uni-muenchen.de, or by airmail to: 11th IEC 2003, Prof. Dr. Thomas Heinzeller, Anatomische Anstalt der LMU, Pettenkoferstrasse 11, D-80336 Muenchen, Germany. More information is available on the web site: www.iec2003.uni-muenchen.de