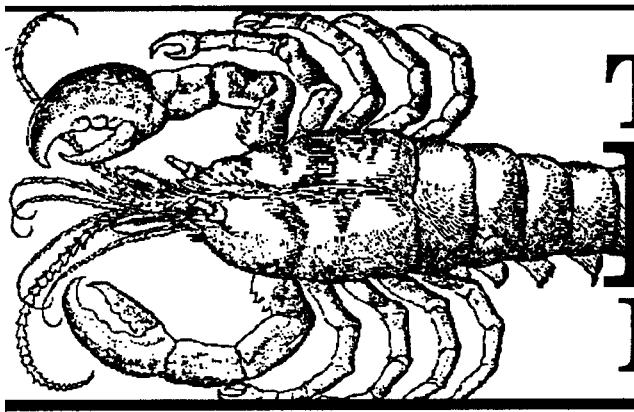
VOLUME ~~THREE~~ FOUR JULY 1991 NUMBER TWO



The Lobster NEWSLETTER

RECENT EVENTS

"Mini-symposium" on the Biology of *Homarus americanus*

The National Shellfisheries Association (USA) held its annual meeting in June 1991, and hosted a day-long session on the biology of the American lobster. Approximately 40 "lobster people" from the USA and Canada attended. During the formal session, moderated by Lew Incze and John Pringle, 22 papers and posters on topics including behavior, demography, migrations, growth, and larval recruitment were presented. Abstracts of the papers and posters have been published in the Journal of Shellfish Research.

In addition to the formal sessions, a considerably less formal two hour discussion focussed on ecology and fisheries, organized around a series of questions dreamed up by the perpetrators, Incze and Pringle. We thought it would be useful to summarize the discussion for the readers of The Lobster Newsletter.

CONTINUED ON PAGE 2

PERSPECTIVE

On the Apparent Resilience of Spiny Lobster Stocks to Exploitation

FROM: D.E. POLLOCK, R. MELVILLE-SMITH AND A.C. COCKROFT

There is a growing body of evidence suggesting that rates of both growth and reproduction in many marine invertebrates, including spiny lobsters, are food-limited, and hence at least in theory, density-dependent. If food (and often shelter-space) is assumed limiting in pristine lobster populations, and if food quantity and quality remain fairly constant, then lobsters of low density stocks, caused by decades of intensive fishing, could have increased rates of growth and egg production due to excess food. Chittleborough (1976, 1979) demonstrated this response in the serially-spawning spiny lobster *Panulirus cygnus* of Western Australia. Females apparently increased their normal frequency of spawning as stock densi-

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RESEARCH NEWS

Intertidal Settlement by pueruli of *Jasus edwardsii* in New Zealand

FROM: JOHN BOOTH

Settlement of the puerulus stage of the red rock lobster *Jasus edwardsii* near the coast of New Zealand takes place over a wide depth range (Booth et al., 1991). It occurs intertidally, and, as determined on our "closing crevice collectors," it also takes place down to depths of at least 50 m. The number of individuals settling generally increased with depth to about 10-12 m, then decreased with increasing depth and distance from shore. An ability to settle over a wide depth range may improve chances of recruitment in this species. Most of the coastline of New Zealand where *J. edwardsii* occurs is subject to large, oceanic swells. Turbulence at the sea-shore interface due to swells is greater near the surface than at depth, making settlement in deeper waters advantageous if this factor alone is considered.

Significant intertidal settlement by *J. edwardsii* may mean this species is unique among palinurids. Intertidal settlement has been followed at Castlepoint (on the east coast of North Island) for various periods since the early 1960s (Booth, 1979),

CONTINUED ON PAGE 3

RECENT EVENTS

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Is egg production a useful predictor of future fisheries yields?

Discussion of this question pointed out that in theory egg production *should* be a useful predictor, but that in practice, there have been no success stories. The lack of success can be attributed, at least in part, to high mortalities during the egg and larval stages. The group seemed to agree that other indices, such as larval settlement or pre-recruit abundance might present better chances for success.

Can we accurately measure larval production?

The word *accurate* in the question received a lot of attention, and there was general agreement that while accuracy was too much to ask for, precision was possible. All those who sample the larval stages report tremendous variability, whose sources probably include location, time, oceanographic features, and undoubtably wind conditions. There was consensus that, to get better estimates of larval abundance, we need more intensive sampling and more knowledge about larval behavior.

Are distant sources of reproduction important to local recruitment?

The brief answer to this was maybe, but we really don't have a clue. In southern New England, the inshore-offshore migration of adults may provide a mechanism for recruitment to distant populations, as may long distance larval transport. But the real question may well be whether levels of egg production influence recruitment levels (question 1, above). If not, the question is moot.

Do wind direction and velocity play a part in the distribution of larvae?

Yes, the larval samplers in the crowd said, but in most (not all) cases they did not have statistical evidence to support their contention. However, markedly different abundances have been seen on windward and leeward shores of points, and with offshore and onshore winds. Conclusion: wind is probably important, but better evidence is needed.

Is cobble substrate the primary habitat for the early benthic phase?

This question precipitated the most lively discussion of the session. There is no doubt that cobble is an important habitat for the newly settled lobster, as well as for younger juveniles. However, the relative importance of cobble versus other habitats was debated vigorously, with emphasis on the use of marginal habitats when cobble is not available. Much of the vigor in the discussion stemmed from questions about the Wahle-Steneck hypothesis (Wahle and Steneck, Mar. Ecol Prog. Ser., 69: 231-243), that limited availability of cobble habitat acts as a bottleneck to recruitment. Participants pointed out that habitat use by young juveniles varies considerably, and that although cobble may be preferred, other habitats (mud, mussel beds, eelgrass) may be used if cobble is not available. The emphasis was placed on shelter-providing habitats, as opposed to specifically cobble habitat. There seemed to be a general consensus that cobble may be most important, but the plasticity of shelter-related behavior suggests that many habitats are used and may be significant to the overall yield.

Do larger lobsters (>60mm CL) move to areas of reduced densities?

This question, with its roots in the discussion of the bottleneck hypothesis above, also provoked considerable discussion. There seemed to be no quarrel with a slightly different statement, that "lobsters, as they become larger, move greater distances." The bottleneck in the discussion seemed to be the notion of diffusing from areas of high density to ones of low density after a certain size was reached. No consensus was reached about this question, but it highlighted the problem of understanding the relationship among habitat, population density, lobster behavior, and demographic consequences.

The discussion was scheduled for two hours, which proved to be far too short to address the many questions arising in the study of *H. americanus* ecology and fisheries. All the participants agreed that the discussions were useful and should be continued at another time.

The Lobster NEWSLETTER

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RESEARCH NEWS

CONTINUED FROM PAGE 1

with spectacular numbers occurring there late in July 1990. The intertidal collecting area is a sheltered stretch of rubble at the eastern end of Castlepoint Bay. Many of the rocks, sedimentary in origin and 6-30 cm in diameter, are heavily indented with depressions and pholad (burrowing bivalves) shafts. The near-shore subtidal part of the beach, down to about 2m depth at low-water, consists of sand interspersed with a few large (>2m) boulders, and a scattering of smaller ones. Both the intertidal and subtidal areas are periodically subject to sanding.

We searched about 4000 m^2 (120 m long by 33 m wide) of intertidal rock that was free of sand in July 1990. Almost 1000 pueruli and early post-pueruli were taken in one hour by two people! Up to 50 animals, and frequently more than 10, hid under individual rocks. Numerous antennae protruded from the underside of rocks partly submerged in 1-10 cm deep pools. We also found animals on damp surfaces and in holes out of the water. Most of the lobsters caught were pueruli at all stages of development, but there were also some first- and second-moult post-pueruli. Many animals remained after the incoming tide made further search impossible.

At night, animals walked out into the open pools. In early morning, transparent pueruli lay alive on exposed rock surfaces; I assume these animals had come ashore the previous night.

The settlement was highly focused. The greatest number of animals was in the mid to low part of the collecting area, and about central along its length. Searches by divers of the rock area below low tide level resulted in the capture of very few animals. Shore checks made of what seemed to be favorable settlement areas (some of which had yielded animals in the past) at various distances 1-100 km to the north and south resulted in no captures. Monthly searches at Castlepoint since July have resulted in significant, but much smaller, collections.

Opportunities such as this to follow natural settlement in palinurids are rare, and this observation is of ecological and behavioral significance. Anecdotal evidence points to net transport in Castlepoint Bay being towards the search area. But why did animals settle intertidally in such numbers when there appeared to have been suitable subtidal substrate available nearby? The July 1990 catches were not unique; monthly checks of the same shoreline in the early and mid 1960s each also resulted in catches of several hundred animals (our unpublished data). Are pueruli being attracted to the intertidal zone at Castlepoint?

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Suspension Feeding By Early Juvenile American Lobsters

FROM: KARI LAVALLI
AND GEOFF TRAGER

Until recently, almost nothing was known of the habits of newly settled post-larval and early juvenile (< one year old) American lobsters. However, recent studies have begun to shed some light on their behavior and have sparked new questions concerning food aquisition. Foraging for food outside of their shelters seems risky, since both laboratory (Lavalli and Barshaw, 1986; Barshaw and Lavalli, 1988) and field (Roach, 1983; Wahle, 1990) studies have revealed that newly settled lobsters are very vulnerable to predation by fishes. Early juveniles did not leave shelters to forage during an eight-month laboratory study (Barshaw and Bryant-Rich,1988). Instead, they were observed to pleopod and expodite fan at the entrance of the burrow, thereby drawing a volume of water towards the lobster. Barshaw and Bryant-Rich (1988) predicted that lobsters derived some of their food from this water.

Lavalli and Barshaw (1989) demonstrated that post-larvae and early juveniles could indeed remove both plankton and fluorescent particles (1 mm to 70 um) from the water column using self-generated pleopod and expodite currents. Both investigators also demonstrated that early juvenile lobsters could survive on a planktonic diet; Lavalli (1991) extended the original survival study (Barshaw, 1989) past Stage VI to Stage IX, approximately the end of their first season of growth and the beginning of the overwintering period. Lobsters were able to survive and grow on zooplankton diets, consisting primarily of copepods, crab larvae and barnacle nauplii, in size ranges of 1mm to 95um. However, neither of these studies addressed the mechanisms by which lobsters gather planktonic food.

We modified a schlieren, laser-backlit, video system (described in Strickler, 1985) to examine early juvenile lobster feeding behavior. Stage V and VI lobsters (just post-settling) were glued to insect pins and positioned in a flume to obtain views of their mouthparts. The mouthparts were illuminated with fiber optic lights, while the laser backlighting illuminated the zooplankters in the surrounding water (Figure 1). We could keep track not only of the paths of the zooplankters, but also of the movements of the third and second maxillipeds, walking legs, and claws.

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RESEARCH NEWS

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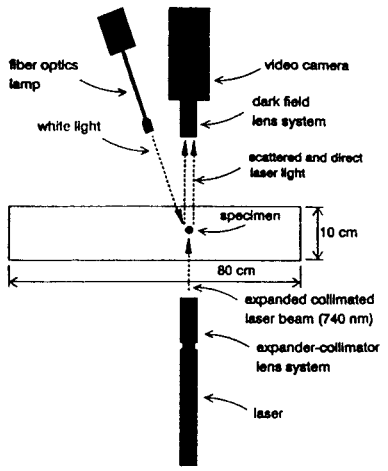

Figure 1. Experimental chamber and filming apparatus for feeding observations.

These early benthic stage lobsters used the techniques of both suspension and raptorial (from *raptare*, meaning to seize) feeding, depending on the zooplankton. Small copepods (500 um or less) were typically captured when the third maxillipeds swept over them and pinned them behind a mesh of setae located along the medial edges of the endopodite segments (Figure 2). They were then transferred to the dactyls of the second maxillipeds. The three terminal segments of the second maxilliped endopodite would either move to push the captured particle toward the esophagus or, in the case of material collected by grooming activities, would move upward and laterally to expel the material into the exopodite current. The exopodite current flushed expelled material out of the mouth region. This feeding mode is clearly that of suspension feeding — a mode which lobsters were previously thought to be incapable of performing. Less frequently, zooplankton were captured by the second maxillipeds directly (again, a form of suspension feeding), by the chelate walking legs aiding the third maxillipeds, or by the legs directly (raptorial feeding).

Larger zooplankters (800 um or greater) were captured most frequently directly by the chelate walking legs. The walking legs were used, but less frequently, in combination with the third maxilliped sweeps and sometimes the third maxillipeds captured the organisms directly. Infrequently, zooplankton were captured by the larger claws, but transfer to the mouth was uncoordinated and involved scraping attempts by the third maxillipeds and grabbing and yanking of the item by the chelate walking legs. With the exception of the third maxilliped captures, these methods were clearly that of raptorial feeding.

Currents generated by the lobster itself were used both before and during captures. The pleopod current was used to draw a new volume of water towards the lobster (Figure 3). A current created by the exopodites of the maxillipeds was used most frequently (either alone or in combination with the pleopod current) to draw particles near the head into the mouthpart region or to flush them out again. The lobsters we observed were good at catching planktonic prey: of 134 attempted captures, 78% were successful.

Homarus americanus, in the V and VI stages, seems to have a remarkable ability to detect the position of zooplankters prior to capture. Jan Factor, of SUNY-Purchase, and one of us (Lavalli) examined the setal distribution of early juvenile lobster mouthparts. We found fields of serrate, simple, and plumose setae along the edges and surfaces of the second and third maxilliped segments. Some or all of these setae may serve a mechano- and/or chemosensory function which could aid the lobster in detection of potential food items, much in the same manner that copepods are able to detect the presence of an algal cell (Strickler and Bal, 1973). However, more work is needed to determine the exact functions of these setae.

Early juvenile lobsters are capable of suspension feeding on small zooplankton suspended in the water column. They are also capable of capturing larger zooplankters raptorially with their walking legs and claws. How often these types of capture modes are used versus capture of organisms within the sediment of their burrows, or directly outside the entrance of their burrow (they

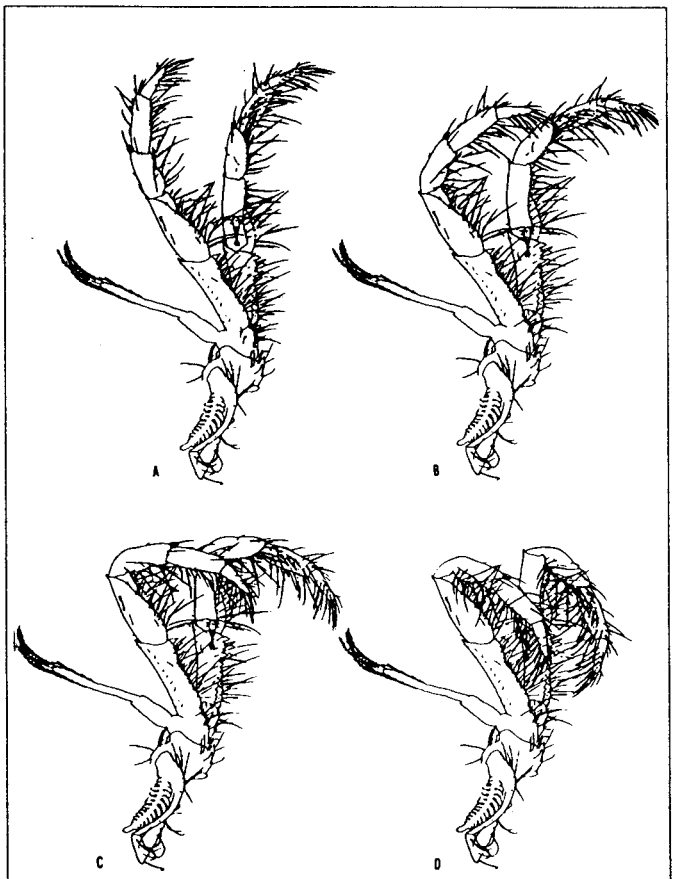

Figure 2. Typical third maxilliped sweep which pins captured material behind a mesh of setae.

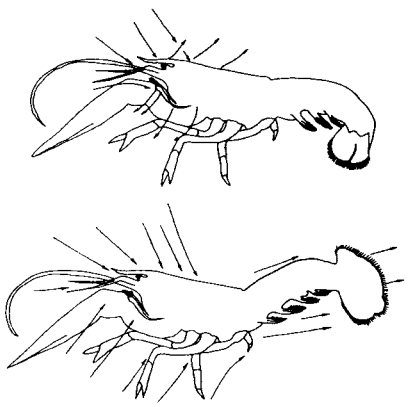

Figure 3. Flow pattern formed by the exopodite current. Bottom: Flow pattern resulting when both the exopodite and pleopod currents are in motion.

have been observed to lunge after amphipods) remains unknown. However, it is clear that early juveniles can survive and grow, in the laboratory, for a significant period of time on diets of suspended zooplankton. This ability to feed on particles suspended in the water permits early juvenile lobsters to fed within the shelter during a period when they are extremely vulnerable to predation. As they grow larger and develop their asymmetrical claws, reliance on suspension feeding decreases and raptorial feeding increases. Finally, active foraging outside of their burrows using both claws and walking legs will become the sole source of food.

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Note: A video record is available for those who are interested in seeing these captures by early juvenile lobsters. If you wish, please send Lavalli a blank tape (in half-inch VHS format) at the address below and she will return it as soon as possible.

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Boston University Marine Program
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PERSPECTIVE

CONTINUED FROM PAGE ONE

ties declined and per capita food supplies presumably increased. However, Morgan (1972) studying the same species demonstrated neither geographical nor inter-annual variations in brood sizes, which might have been correlated with different growth rates.

In contrast to the above, annual spawners such as the cold-water species *Jasus lalandii* of the South African west coast, are apparently incapable of altering moulting and spawning frequency, and are locked into a regular annual cycle. Recent sudies in South Africa have clearly demonstrated both geographical and inter-annual variations in brood sizes of female *J. lalandii* (Beyers and Goosen 1987, Melville-Smith and Goosen in prep.), which correlate with variations in somatic growth rates. In areas where, or years when, food availablility is high, both mean male moult increment and female brood size are large. These changes may be due to changes in lobster densities, but it is far more likely that changes in production of important benthic food items in the variable Benguela upwelling system are responsible for the observed variations in lobster growth rates. More research is underway to investigate this further. It would appear, however, that food energy in *J. lalandii is* channelled mainly into somatic growth in males, whereas egg production is the favoured route for energy flow in females. Growth increments of female *J. lalandii* are very much smaller than males (usually about 20%), which explains the large discrepancy in mean and maximum sizes between the two sexes.

As Chittleborough (1979) suggested, density-dependent changes in growth and reproduction are responses which might help explain some of the apparent resilience of certain lobster stocks to severe fishing pressure. What of *Homarus americanus*? Is there evidence of serial spawning (eg. Campbell 1983 p. 1674), possibly in response to reduced adult densities? Or are the larger brood sizes and faster growth rates occurring in response to increased food availability as both juvenile and adult lobster densities continue to be reduced by intensive harvesting? Answers to questions such as these are needed if biologists are to explain how heavily fished lobster stocks, with concomitantly reduced broodstock strength, manage with apparently undiminished recruiment over years.

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BOOK REVIEW

Crustacean Sexual Biology

Raymond T. Bauer and Joel W. Martin, editors. 1991. Columbia University Press, 562 West 113th St., New York City, NY 10025 ISBN 0-231-06880-8, 355 pp, acid free paper, illustrated US$70.00

REVIEWED BY L. S. QUACKENBUSH

Ray Bauer and Jody Martin organized a symposium at the American Society of Zoologists meeting of 1988 in San Fransico with help from the Crustacean Society, Invertebrate Zoology Division of ASZ and the Systematic Biology program of NSF. This book is the tangible product of that symposium. Anyone who attended the symposium will certainly recall the interest and excitement that was generated by the topics presented in the text.

The editors sought to present both recent work and a synthesis of past achievements in the sexual biology of crustacea, and their contributors have succeeded. Each of 18 chapters is preceded by an informative abstract. The illustrations are of exceptional quality (old FSU grads refer to this as Felgenhauer quality). Each chapter includes its own reference list, the citations are predominately from1970-1990 with a few reviews and some old work as well (from as far back as1850). Most chapters have a **Future Directions** section that should help graduate students focus on current problems, and faculty on the look out for new research.

The title of the symposium: Sex Attraction, Mating Behavior, and Insemination in Crustacea outlines the text. There are 3 chapters that could be classified under sex attraction, 7 chapters devoted to mating behavior, and 8 chapters which focus on insemination. Though the well studied decapods are represented in all sections, they have included very informative work on amphipods, isopods, stomatopods, cirripeds, copepods, and remipedes. I was especially taken by the chapters on insemination: they are well written, illustrated with line drawings, photographs and current data. A minor drawback to the volume, and a personal prejudice, was the lack of a contribution devoted to female gonadal development and related topics.

By the time I was asked to review the book for the Lobster Newsletter, my own copy already had been ordered. Editor J.S. Cobb suggested the order be cancelled since I would receive the review copy as well. However, my graduate students absconded with my personal copy so this one will be kept. I also have two copies of the two-volume Biology and Management of Lobsters in the laboratory, but they always are in the hands of the students. The same pattern no doubt will hold for Crustacean Sexual Biology. I will refer to this book as a resource for lecture and research information for the next ten years. Everyone is encouraged to order a copy for their school library; those in the business of crustacean sexual biology will find this book a "must-buy" item. I want to thank the editors for a job well done, in a timely fashion.

L. Scott Quackenbush
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LETTERS

To the Editors:

I am working on growth and mortality of larval *Panulirus argus* using modal progression analysis. I would be grateful if you could publish my request to get in contact with people working along this line. If readers of The Lobster Newsletter have published any papers on this topic, it would be very useful to receive them. Thank you for your cooperation.

Irma Alfonso Hernandez
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CUBA

To the editors:

I thought readers of the Lobster Newsletter might be interested in the following early account of *Panulirus ornatus*. It comes from Louis Renard's "Poissons, ecrevisses et crabes de diverses couleurs et figures extraordinaire, que l'on trouve autour des Isles Moluques..." (Amsterdam, 1719 &c), quoted in Pietsch, T. W. : Archives of Natural History 18: 1-25 (1991):

> "...the Ecrevisse des Montagenes, the spiny lobster *Panulirus ornatus* (Fabricus) likes to eat fruit, and lays red-spotted eggs as large as those of a pigeon."

Have we got it all wrong?

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ANNOUNCEMENTS

European Crustacean Conference

An international meeting on Crustacea is planned for August or September, 1992. Five main topics are suggested: Phylogeny, Aquaculture, Nutrition, Endocrinology and Ecology. For further information, contact:

Pierre Noel
Museum National d'Histoire Naturelle
Laboratoire de Biologie
de Invertebres Marins
55 rue de Buffon, 7-5231 Paris, France

Crustacean Society

The annual meeting of The Crustacean Society will be held in Charleston, South Carolina, USA June 11-14, 1992. Three concurrent sessions, poster presentations and at least one symposium are planned. For further information, contact:

Elizabeth L. Wenner
South Carolina Wildlife and Marine Resources Department
P.O. Box 12559
Charleston, SC 29412 USA
Telephone: 803-762-5050

Newsletter Mailing List Available

The major reason for the existence of The Lobster Newsletter is to enhance communication and cooperation among lobster researchers around the world. A number of readers have suggested that direct communication via letters, phone or fax would be enhanced if they had the addresses of the readers of the Newsletter. We agree. If you would like to have a copy of our mailing list, write to John Pringle. and, if you have not provided us with your telephone, Fax or e-mail address, please do so! It will become part of the mailing list, and make communication with you that much easier.

For a copy of the LNL Mailing List, write:

Dr. John Pringle
Fisheries and Oceans
P.O. Box 550
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Aquaculture in Tropical Areas

This book, edited by S. Shokita, K. Kakazu, A. Tomori and T. Toma, is now available in English, recently having been translated from Japanese by M. Yamaguchi. It is "state-of-the-art" on Okinawan aquaculture, according to the publisher; a claim we cannot refute, not having received a copy for review. There are 23 contributing authors.

The first three chapters give a broad overview of the history, prospectives and environmental characteristics of aquaculture in tropical Japan. The next five chapters cover the biology, culture methods, markets etc. of seaweeds, fishes, crustaceans, molluscs and other organisms.

We were sent a photocopy of a section on spiny and slipper lobsters. The species occurring around the Ryukyu Islands are listed: *Panulirus japonicus, P. longipes, P. penicillatus, P. versicolor, P. ornatus, P. homarus, Scyllarides squamosus, S. haanii, Parribacus japonicus,* and *Thenus orientalis.* A brief coverage of lobster ecology and life history information is provided. They suggest a more aggressive resource management plan is required, as is some method of resource enhancement. They note that mass seed production has not been successful, and recommend the collection and growout of juveniles. Development of artificial nursery grounds to provide substrate for settling pueruli and juveniles has been attempted. The authors hint of lobster habitat deterioration by urging management of not only the resource, but of the lobster food chain.

The above is the first material sent The Lobster Newsletter from Japan. There are some intriguing problems and some interesting solutions proposed. We have been given just enough to want more. Might some enthusiastic lobster biologist in Japan take pen in hand or put finger to keyboard and fill us in?

Midori-Shobo Co. Ltd., Publishers
Ikebuukuro Nishiguchi Sky Building,
2-14 Ikebukuro,
Toshima-ku, Tokyo 171,
Japan

Lobsters: Florida, Bahamas, the Carribbean

BY MARTIN A. MOE, JR.

We received this interesting looking book in mid-September. A review will be prepared for Volume 5, (1). The author has had a long involvement with lobsters when a resident of Florida for 10 years. He originally began it as a guide for recreational lobster divers, but it appears to have become much more comprehensive.

Green Turtle Publications
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Plantation, FL 33318, USA

FISHERIES UPDATE

Deep Water Survey for *Panulirus ornatus* in Papua New Guinea and Australia

FROM: J. PRESCOTT AND R. PITCHER

The ornate spiny lobster, *Panulirus ornatus*, supports a regionally important fishery in Western Province, Papua New Guinea and the Torres Strait Islands, in northeastern Australia. Annual catches average about 250 tonnes tail weight, but have exceeded 400 tonnes on occasion.

Lobsters are fished primarily in central Torres Strait between Cape Yorke and the southern coast of Papua New Guinea. In this area most of the lobsters are juveniles and no breeding occurs. Few fishermen have seen an ovigerous female. Until this study the only area known to have a significant breeding population were the reefs surrounding Yule Island on the eastern side of the Gulf of Papua, about 500 kilometers northeast of the principal fishing ground. This breeding population supports a small, seasonal, artisanal fishery.

Lobsters migrating across the Gulf of Papua were fished intensively by trawlers between 1973 and 1983, during which time the catch in one season exceeded 200 t. A smaller trawl fishery developed around the same time in Torres Strait. However, concerns were raised that trawling was depleting the major breeding ground and the activity was banned in 1984. This management measure was invoked at considerable cost in terms of reduced catch, particularly to Papua New Guinea fishermen.

Lobsters at Yule Island are in very poor physiological condition and most disappear by the end of the breeding season suggesting that poor condition led to catastrophic mortality, probably during ecdysis at the end of the breeding season. Recent studies have confirmed that this population suffers extremely high mortality as the breeding season progresses.

The Yule Island population can only account for about one percent of the lobsters that migrate from Torres Strait, according to recent population estimates. Obviously, a very large number of lobsters were leaving the fishery for an unknown destination. Where these lobsters went and determining if their mortality rate was the same as those at Yule Island, was the focus of a study by the Papua New Guinea Department of Fisheries and Australian CSIRO in 1989/90.

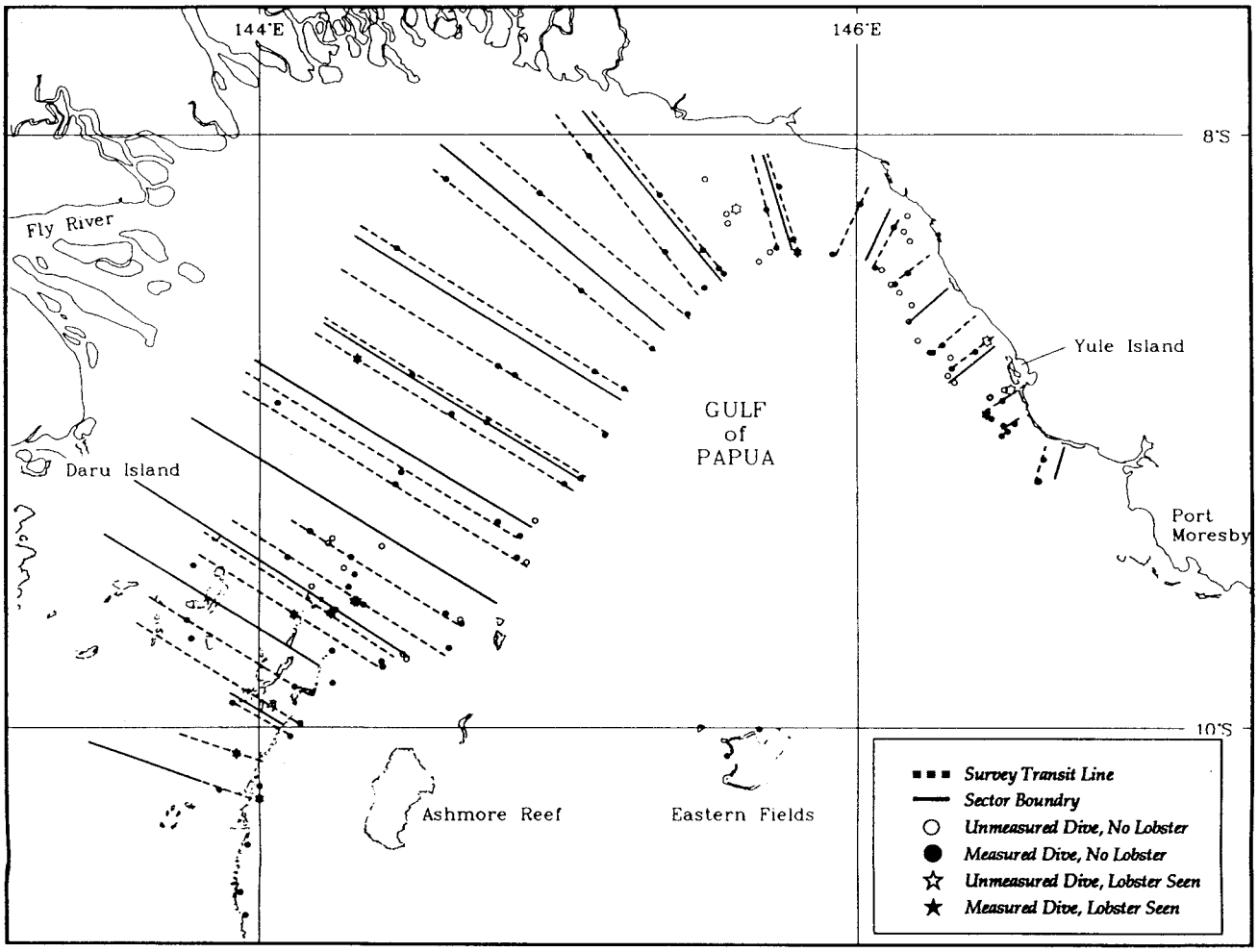
We suspected the destination of lobsters emigrating from Torres Strait was the continental shelf edge of the Gulf of Papua and the Far Northern Great Barrier Reef. Previous methods used for sampling migrating lobsters were inadequate for the proposed survey of this area. Because of strong currents and necessity to search rugged bottom habitat, the most suitable method for the study was a manned submersible. The research submersible DELTA was contracted to carry out the survey. This submersible carries a pilot and one observer, and various camera sampling equipment.

We divided the study area into 15 sectors, each 15 nautical miles wide along the edge of the shelf edge (see map). Within each sector two survey transit lines were selected at random. Bottom topography and benthic habitats along each line were recorded using the ship's echo sounder. DELTA was used to search for and count lobsters along 0.5 nautical miles transects at the shelf edge, at two random points along the transit line on top of the shelf, and at other sites where the echo sounder indicated the habitat might be suitable for lobsters. During each transect, substratum type and biota were recorded on video and still cameras. The effective search path width was estimated by the observer. Where shallow reef areas were present adjacent to the submersible dive sites, surveys were made by divers using hookah to estimate lobster densities in the shallow habitat.

A total of 132 dives was made in the DELTA submersible during the survey. Eighty-eight of the dives were along measured transects, which traversed 78 km of seabed. The total area surveyed on these submersible dives was estimated to be 342,000 m2.

Eighty-four submersible dives made outside of the known breeding areas around Yule Island yielded sightings of only 10 lobsters. Those 10 were seen on 5 of the 84 dives. Seven of these were found on an isolated deep (60 m) mid-shelf reef, two on the shelf-edge (~120m deep) and one in a fish excavation on soft substrate (60 m). Lobsters were seen on three of four submersible dives made within the known breeding area.

Forty-four dives by the submersible were made in the southwestern part of the study area, encompassing the outer reefs of the Far Northern Great Barrier Reef and shelf edge beyond the outer reef slope. On 7 of those 44 dives, we encountered 79 lobsters. Seventy-two of these were seen during three of the dives. Most of the lobsters were females and many were ovigerous. Areas of higher lobster abundance were associated with certain physical characteristics: high relief, strong currents, close proximity to the edge of the continental shelf and depths ranging from 40 to 120 meters. The depth at which we observed *P. ornatus* in breeding condition is significantly deeper than in previously known breeding areas. The overall density of lobsters in the Far Northern Great Barrier Reef area of the survey was about seven per hectare of bottom surveyed, which compares with a density of about three per hectare (excluding the prerecruit year class) in the area where the fishery operates in central Torres Strait. Thirty-seven lobsters were observed by divers on shallow reefs near the outer Far Northern Great Barrier Reef. The average density of



The Gulf of Papua and far northernGreat Barrier Reef showing the area surveyed. Outer dive sites coincide with the edge of the continental shelf.

these lobsters was about one lobster per hectare.

The results of this survey indicate that the shelf edge outside the Far Northern Great Barrier Reef may support the most important breeding population for the Torres Strait fishery. Because very few lobsters were found in the Gulf of Papua, we presume that the mortality of lobsters migrating into the Gulf of Papua is extremely high. If the suspected importance of the Far Northern Great Barrier Reef breeding population is confirmed then the banning of trawling for lobsters migrating across the Gulf of Papua will have proved to be overly conservative management measure costing the fishery an average of more than 100 tonnes of lobster tails annually.

From a purely biological and evolutionary point of view it is interesting to speculate that lobsters migrating across the Gulf of Papua have made a navigational error and missed their intended breeding habitat outside the Far Northern Great Barrier Reef. Could as many as half a million lobsters make this mistake each season?

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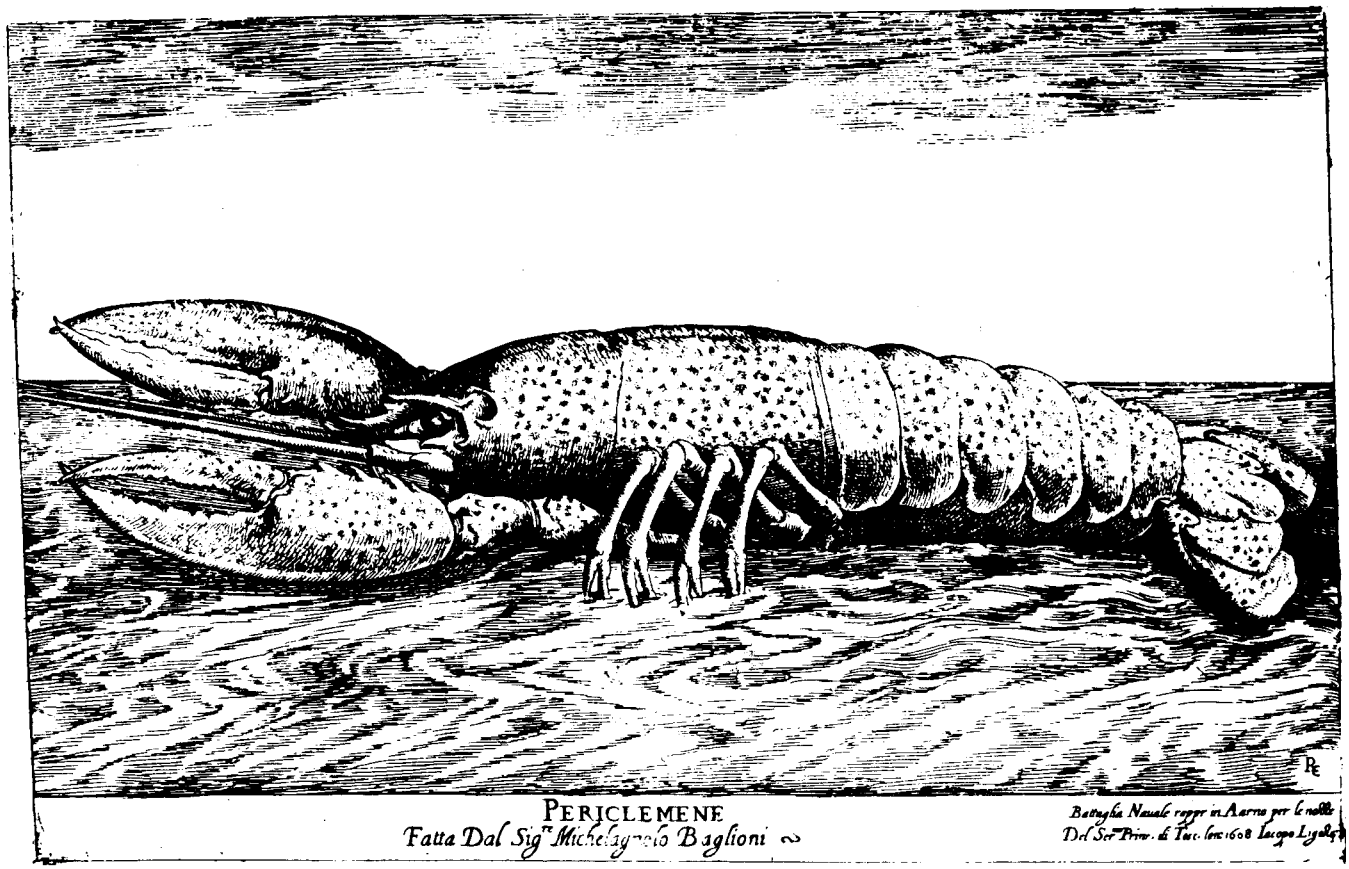

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