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The Lobster NEWSLETTER

RESEARCH NEWS

Jasus Females are Vulnerable to Mate Availability

From: Alistair MacDiarmid, Rob Stewart, and Megan Oliver

Catches of a number of mature but apparently non-mated female red rock lobsters, *Jasus edwardsii*, in Fiordland, New Zealand in the last two years highlights a potential problem in this and other fisheries that exploit principally males. Fishing, especially when exploitation rates are high, not only decreases the abundance and mean individual size of the target species through the removal of larger, older individuals, but may also skew the population sex ratio if one sex is exploited more than the other. This is currently the case in some areas of the New Zealand fishery for red rock lobsters, *J. edwardsii*, where, for a number of reasons, males make up 80% or more of the landed catch.

Recent work on *J. edwardsii* in New Zealand and *Panulirus argus* in the US has highlighted the importance of large males in successful reproduction. Females mated by large males have larger clutches than those mated by small males, and large males are capable of mating more females than are small males (MacDiarmid & Butler in press). Consequently, females prefer large males as mates and preferentially shelter with them in the interval between moulting and mating . In *Jasus* spp, the spermatophore deposited by the male on the female's sternal plate during copulation is short lived (minutes) and must be immediately used by the female to fertilize her one annual clutch of eggs. Therefore, a mate must be available when the female's eggs are mature and ready to be extruded. How long is this mating window and what are the consequences for the female if a suitable mate is not found?

In 1997, we addressed these questions in a laboratory experiment in which female *J. edwardsii* were randomly assigned to one of six treatments where mates were made available 30 days prior to mating, the day of mating, or 5, 10, 15 and 20 days after the predicted day of mating. The day of mating was predicted from the regression of molt-mate interval on day of molting and female carapace length, established from experiments in the previous two years. We monitored the tanks daily for courting, copulation, egg bearing and mortality and measured the size of any resulting egg clutches. Under this regime we hoped to determine the duration of the female mating window, the period in which females could court, mate and successfully fertilize a full clutch of eggs. Was it a period of days or was it weeks?

We found that courting and copulatory activity, as well as egg extrusion and clutch size, are all depressed by up to 50% if males are unavailable 5 days after the predicted day of mating and by 98% after a 10 day delay. Any further delay results in no reproductive behavior at all. These results indicate a narrow mating window for female *J. edwardsii*. Mating must take place within a day or two of when a female's eggs are ripe for

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a normal sized clutch of eggs to be produced.

Thus, for female *Jasus* there is a strong necessity to locate a mate within a narrow time frame and this indicates why females preferentially shelter with males for the 10-40 day period between molting and when her eggs are ready to be fertilized.

We are aware that in some situations, such as in live holding plants where males and females are kept separate during autumn (the time when mating normally takes place) females will sometimes extrude their egg mass but the eggs do not attach to the pleopods. But what is the fate of females that do not have a male available at the required time and do not extrude their clutch of eggs? Do they suffer any long term consequences? This is of potential importance to the fishery now that apparently unmated, mature females are turning up in the population.

To address this question, we kept the mated and unmated females from the experiment just described until the mating season this year and monitored the tanks daily for molting and mortality. We found that unmated females had resorbed their eggs, resulting in strong pink staining of the haemolymph and muscle tissue with egg derived pigments. They were also weak and lethargic, possibly because the large mass of eggs in the body cavity inhibited feeding and normal ogan function. In contrast, females that extruded a full batch of eggs had a clear white abdomen with normal colored haemolymph and they were more active.

One year after mating, females normally have large ovaries packed with another clutch of developing oocytes. In contrast, one year after their predicted day of mating the ovaries of surviving non-mated females were atrophied, with only small regions of normal egg development. Although most of the surviving non-mated females mated in the subsequent breeding season, their clutches were very small compared to normally breeding females.

These results contrast with what happens in other species of spiny lobster. For example, in *P. argus*, copulation and egg laying can be separated in time by up to 40 days because the male deposits a spermatophore, which develops a hard outer layer thereby protecting the sperm within. The female scrapes away this layer to expose the sperm and fertize her eggs. Thus, she can mate with any male she encounters well before egg extrusion is necessary. In addition, if a female *P. argus* fails to find a mate she routinely extrudes the current batch of unfertilized eggs (MacDiarmid & Butler in press). All that is lost is the one clutch of eggs.

In summary, female *J. edwardsii* are particularly vulnerable to the non-availability of mates. Males must be available in a very narrow time window for successful mating and fertilization. If not, females often resorb their current clutch of eggs, and have impaired reproduction in the subsequent breeding season.

The management implications are clear. If egg production is to be maintained, the fished population must contain enough males of size sufficient to fertilize all the eggs a female can produce. Further work is planned to document the incidence of unmated but mature females in the Fiordland fishery and to determine at what sex ratio and male size structure the incidence of unmated females becomes unacceptably high.

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Sperm Limitation in Exploited Spiny Lobsters

From: Alistair MacDiarmid and Mark Butler

Changes in the abundance, size structure and sex ratio of lobster

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populations subject to heavy exploitation by fishermen can have large and consequential effects on mating systems, and thus on reproductive output. Yet, the specifics are largely unknown for most species of spiny lobster. We know that male spiny lobsters grow substantially larger than females, and although both male and female size is reduced under severe exploitation, male size declines more precipitously. The reproductive output (clutch size) of females is exponentially related to female size, so a shift toward smaller females in exploited areas has clear implications for reproductive potential. Less clear is the effect of reduced male size on lobster reproductive dynamics.

We have evidence from laboratory experiments on two species of spiny lobsters, the Caribbean spiny lobster (*Panulirus argus*) and the Red Rock Lobster (*Jasus edwardsii*), that the availability of large males has a large, direct effect on female fecundity. For *P. argus* in the Florida Keys, we found that: (i) male size is positively related to spermatophore size, (ii) males vary the size of the spermatophore transferred in response to changes in female size, and (iii) spermatophore size has a greater influence on the consequent clutch than does female size. Female size, male size, and mate order all effect clutch size in *J. edwardsii* from New Zealand. Furthermore, in both species clutches fertilized by small males are significantly smaller than clutches fertilized by large males. This is strong evidence for sperm limitation under exploitation, and it applies to two species in separate genera that dwell in very different habitats on opposite corners of the world.

We will be continuing our collaborative research on this aspect of lobster reproductive biology over the next few years, thanks to the generous support of the U.S. National Science Foundation and the N.Z. Foundation for Research, Science, and Technology. Along with the cross-species comparison, we will be capitalizing on the existence of long-standing marine reserves and adjacent fisheries in both the U.S.A. and N.Z. for comparisons of fished and unfished populations. Field observations in these areas will thus compliment the laboratory experiments and individual-based modeling we have planned for the next few years.

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The Status of the Three Forms of *Panulirus longipes femoristriga*

From: Hideo Sekiguchi

Panulirus longipes is widely distributed in the Indo-West Pacific as two subspecies - the western spotted leg form, *P. longipes longipes* (distribution includes Thailand, Malaysia, Sumatra, and the Indian Ocean); and the eastern striped leg form, *P. longipes femoristriga* (including Japan, the Mullaccas, Banda, Amboina, north and east Australia, and several South Pacific islands) (Sekiguchi 1991). But both subspecies have also been collected in Taiwan, the Philippines, and Indonesia, where they interbreed and establish intermediate forms (Junio *et al.* 1991).

In the western Pacific, the northern boundary for *P. longipes* accords with the northern limit of coral reefs: it is found mainly in the Ryuku Archipelago and Ogasawara Islands (only *P. longipes femoristriga*), and in the north of Taiwan (both subspecies, with *P. longipes femoristriga* by far the most abundant) (Sekiguchi 1988; Fig. 1).

In Japan, *P. longipes femoristriga* has three forms, distinguished mainly by the color and color patterning of the antennal flagella (Sekiguchi 1991, 1996):

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1. 'Shirahige-ebi', with white or pale flagella with cross-banding
2. 'Aka-ebi', with red-brown flagella without any cross-banding
3. 'Shironuke-ebi', with white flagella without any cross-banding

Shirahige-ebi is abundant but Shironuke-ebi rare in the Ryuku Archipelago. Aka-ebi and Shirahige-ebi are both found in the Ogasawara Islands where they occupy separate habitats, Aka-ebi being by far the most abundant. This suggests that populations of *P. longipes femoristriga* in the two areas are isolated from each other and that genetic exchange has not occurred.

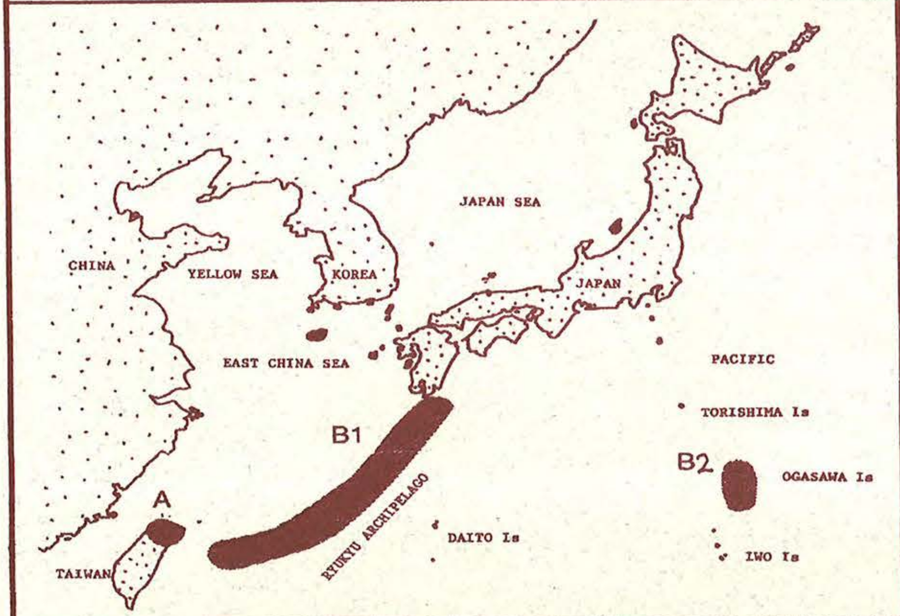

Figure 1: Distribution near Japan of *Panulirus longipes*. The shaded area A is where *P. longipes longipes* and *P. longipes femoristriga* occur together, the two forms of the latter being Shirahige-ebi and hironuke-ebi; B1 is where *P. longipes femoristriga* (mainly Shirahige-ebi) occurs; and B2 is where *P. longipes femoristriga* (mainly Aka-ebi) occurs.

Shirahige-ebi is found in northern and southern marginal areas of the Pacific *P. longipes femoristriga* distribution and Aka-ebi in central regions (Sekiguchi 1991). The distribution of Shironuke-ebi is not well known, but Chan and Chu (1996) say it is found widely but infrequently throughout the Indo-West Pacific.

Chan and Chu (1996) described the morphology and isozyme analysis of the subspecies *P. longipes femoristriga* and erected a new species, *P. albiflagellum*. Their description of *P. albiflagellum* is consistent with Shironuke-ebi. I believe that the three forms of *P. longipes femoristriga* in Japanese and Taiwanese waters should each have specific status. Except for Shironuke-ebi, detailed descriptions are yet to be given.

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Sediment Effects on the Behavior and Survival of Young Juvenile *Jasus edwardsii*

From: Lee Perry

Large numbers of pueruli settle at Gisborne and Castlepoint, on the east coast of the North Island of New Zealand, and it has been asked whether these postlarvae and the young juveniles can survive there given the high

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levels of sand and suspended sediment often seen. I also wanted to know whether young juveniles are at risk from the silt burdens resulting from human activities such as dredging, channel construction, dumping and coastal development.

Lobsters collected at Castlepoint were airfreighted to the Portobello Marine Laboratory near Dunedin. First instar juvenile lobsters were randomly allocated among eleven containers, one lobster in each. They were exposed to sand for eleven days, or to varying levels of suspended sediment from Castlepoint (85 $mg.l^{-1}$, 255 $mg.l^{-1}$, 363 $mg.l^{-1}$, stirred to keep suspended) for four days. There were controls (no sand or suspended sediment).

Mortalities and the presence or absence of specific behaviors (e.g., grooming of the gills for both the sand and suspended sediment treatments, and walking and burying in the sand treatment) were recorded. Grooming of the gills was considered important because lobster gills are multifunctional organs that must maintain direct contact with the seawater drawn into the branchial chamber and are susceptible to fouling. Grooming removes debris from the gills and allows them to function effectively. The frequency of walking was observed, as it has been shown that an increase in activity in fish corresponds with a flee response from a stress-inducing agent.

The juvenile rock lobsters displayed remarkable ability to cope with sandy habitats, and with all the levels of suspended sediment tested. Exposure to sand or suspended sediment did not significantly affect survival, nor did it result in significant change in the time spent grooming or in the time spent walking the container. I also found that first instar juveniles can bury in sand: juveniles were often observed with most of their antennae and abdomen under the sand. Two juveniles were observed completely buried except for the very anterior part of the cephalothorax and the antennules. Similar behavior has been reported for the puerulus stage of other palinurids (e.g., *Panulirus argus;* Calinski and Lyons 1983), but I know of no other species that buries as juveniles.

My laboratory observations of high survival in silty water, an ability to almost completely bury in sand, and an absence of behavioral differences following exposure to suspended sediment and sand suggest that young juveniles of this lobster are well adapted to an environment with both sand and suspended sediment. I postulate that benthic and suspended sediment are used by these lobsters to reduce the risk of predation from visual predators. Visual isolation could be provided by inhibiting light penetration (suspended sediment) and providing cover (suspended sediment and sand).

These results suggest that the high mortality of early juvenile *J. edwardsii* seen at Castlepoint from time to time should not be attributed to the levels of suspended sediment, although the periodic covering by sand of the rocky shore may mean that lobsters are unable to find suitable long-term cover. High survival following exposure to sediment suggests that human activities that elevate concentrations of Castlepoint-type sediment up to levels of at least 360 $mg.l^{-1}$ should not be deleterious to first instar *J. edwardsii* juveniles (Perry 1997).

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Puerulus Shoreward Bound: Sounds Good?

From: Andrew Jeffs

Spiny lobster larvae are often dispersed for thousands hundreds of kilometersres in the sea during their long larval life. At the end of the larval period, the puerulus is faced with the challenge of returning to the coast to settle. This would seem

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to be a daunting task for an animal that is not much bigger than a jellybean and may be a hundred or more kilometersres out to sea. The task is daunting for two reasons. Firstly, the distance to be covered is enormous, especially as the puerulus appears to be unable to feed. Secondly, the quickest trip to the coast would rely on the puerulus being able to determine the direction of the coast from some distance offshore.

Investigating the navigational skills of puerulius is part of a study I am being conducteding on the spiny lobster, *Jasus edwardsii*, in New Zealand. Unfortunately, vVery little is known about the sensory capabilities of puerulius, although some work has been done on larger spiny lobsters and members of closely related groups. Studies on adult spiny lobsters provide good evidence that they have a great deal of visual, chemical and hydrodynamic sensitivity, as well as some magnetic, gravitational and vibrational (sound) sensitivity. This provides a great range of possible cues that might be used for shoreward navigation by puerulius, including navigating by chemical or salinity gradients, wave direction, current direction, magnetic field, and celestial and sound cues.

Underwater sound is one possible navigational cue for puerulius that has received some attention. Waves breaking on the coast generate an enormous amount of underwater sound, some of which can travel for long distances offshore and might be used by the puerulus to navigate to shore. It has been suggested that the long rows of sensory hairs found on the antennae of the puerulus of spiny lobsters are a sound detectors and information from them is used for navigation (Phillips & Macmillan, 1987). The puerulus of more than 6 species of spiny lobsters have now been examined and all contain remarkably similar sensory structures. However, the function and sensitivity of these receptors is yet to be determined (Jeffs et al., 1997).

Some support for puerulus sound navigation comes from a study whereinich found disproportionately high numbers of puerulius werebeing caught in the seawater cooling intake of a power station in New Zealand (Booth, 1989). The authore of thatis study suggested that sound generated by the power plant might be involved in attracting puerulius to the intake. Initial sound recordings taken at the power plant have shown that it does generate a high volume of underwater sound. We aim to examine this further by taking further recordings offshore to the measure the extent and frequency spectra of underwater sound broadcasting out from the power station. In addition, we hope to test the effect of this sound by playing back the power station recordings at other coastal locations where puerulius are known to occur.

If underwater sounds can be identified that attract puerulius it will have obvious advantages for greatly improving the collection of large numbers of seed lobsters for aquaculture and enhancement.

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Dispersal Dynamics of Exploited Species in a Marine Reserve

From: Charles A. Acosta

Marine reserves that function as harvest refuges have great potential for preventing overexploitation and for increasing fishery yields of valuable species. These effects may indeed be the only incentive for developing nations to invest in non-extractive marine reserves that initially have high political and economic costs. However, conservation

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organizations and resource managers are too often faced with the immediacy of establishing reserves in developing countries in the absence of supporting data on the functional effects a particular reserve may have on target populations. What is needed is a pragmatic view that recognizes the urgency of conservation in developing countries and draws from advances in ecological rapid assessment for evaluating reserve function.

For two years, I have been assessing the response of populations of spiny lobsters and queen conch in a recently-designated marine reserve at the Glover's Reef atoll in Belize. Caribbean Spiny Lobster (*Panulirus argus*) and Queen Conch (*Strombus gigas*) are the two most heavily exploited species in many parts of the Caribbean, and the sustainability of their stocks is a significant incentive for establishing reserves. Here I present some preliminary findings on dispersal dynamics of lobster and conch in the reserve and discuss the functional effects of a simple alternative design of the reserve's boundaries (Fig. 1), which were initially designated based on negotiations with conservation, tourism and fishing interests.

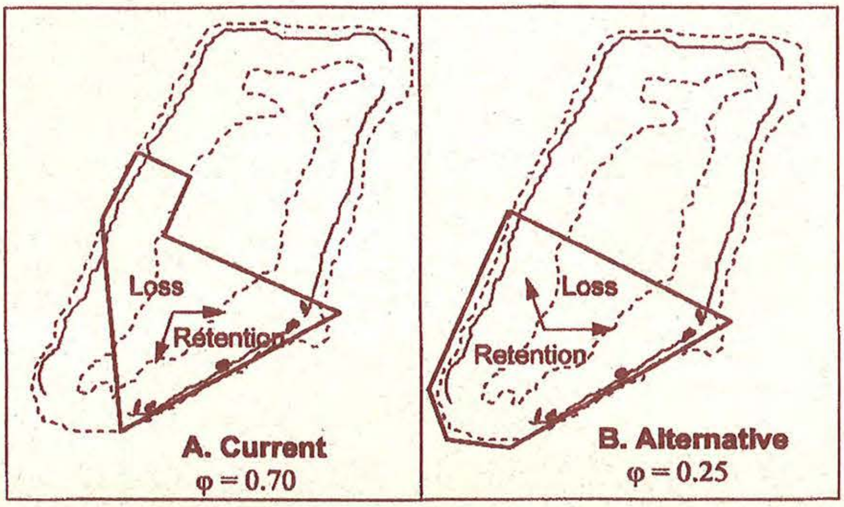

Figure 1. The current non-extractive reserve boundaries at the Glover's Reef atoll, Belize(A) and the alternative reserve boundaries (B). The permeability index (φ) represents the anticipated loss of animals across reserve boundaries.

A key issue in evaluating how well a particular reserve can protect heavily exploited species is to determine the transfer rate or loss of animals from a protected area. The complex movement patterns of juvenile *P. argus* are behaviorally-based (Herrnkind & Butler 1986; Childress & Herrnkind 1994) and strongly influenced by habitat heterogeneity (Acosta in press; Acosta & Butler 1997). Adult spiny lobster movement, in contrast, is phenomenological (e.g., queueing migrations; Herrnkind 1969) or nomadic (Cruz et al. 1986; Herrnkind et al. 1975). Much less is known about the dispersal of queen conch although they sometimes move in aggregations (Stoner and Ray 1993).

Adult lobsters and conch were fitted with ultrasonic tags and tracked daily for up to fourteen days. Movement paths have been measured for only 6 animals (three lobsters and three conch) so bootstrapping was applied to simulate movement of 1000 individuals. I used a correlated random walk (CRW) model with four movement parameters (move length, squared move length, cosine of turning angles, and sine of turning angles) to calculate the net squared displacement of lobster and conch over time. The CRW model, developed by Skellam (1951) and applied to insect movement by Karieva and Shigesada (1983), is appropriate if move paths are characterized by some degree of directional persistence (as opposed to an uncorrelated random walk with equal probabilities of forward and reverse movement directions). The net squared displacement is used instead of net displacement because the former is approximately linear at large numbers of moves, similar to a diffusion process (Karieva and Shigesada 1983).

The model results show that

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lobsters undertaking an intermittent random walk from the center of the reserve could reach the boundary of the fishing zone in 10 days, whereas conch will remain in the reserve indefinitely (Fig. 2).

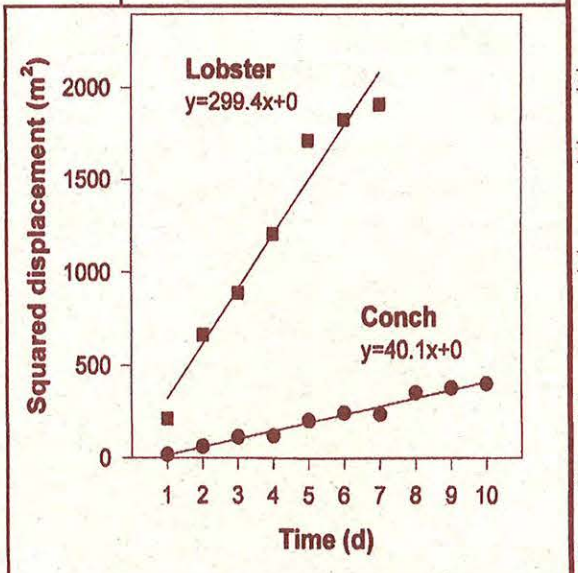

Figure 2. Correlated random walk models for net squared displacement of spiny lobsters and queen conch over time.

The perimeter:area ratio of a reserve and the relative "permeability" of boundaries are one means of comparing the effects of alternative designs of protected areas (Stamps et al. 1987). Therefore, I divided the current reserve boundary and a simple alternative set of boundaries into arbitrary units of "permeability" (i.e., φ = the proportion of permeable to total boundary units). That is, boundaries with the fishing zone are completely permeable within the atoll lagoon, whereas boundaries at the edge of the atoll (forereef wall) are completely impermeable to movement (Fig. 1). In this case, the perimeter:area ratios are similar in both designs. The model results indicate that the exposure of lobsters and conch to harvesting in areas adjacent to the reserve would be almost three times greater in the current reserve than in the alternative design. These results suggest that the boundaries of the current reserve may be adequate for protecting queen conch, but they are largely ineffective for the protection of lobsters.

The dynamics of malfunctioning reserves may have many lessons for conservation. Those who are familiar with the ecology of spiny lobsters and queen conch will find these preliminary results fairly intuitive. An important point is that there is a substantial body of ecological theory that can be applied to pressing conservation problems. But these applications must be made available in user-friendly forms if they are to see widespread use.

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So How Do Spiny Lobsters Form Groups?

From: Stephen Ratchford

The sharing of diurnal shelters is common among the juvenile and adult stages of many spiny lobsters, including *Panulirus argus, P. cygnus, P interruptus, P. ornatus*, and *Jasus edwardsii* (Atema & Cobb 1980), but these lobsters are not always found in groups. Recently settled *P. argus* are solitary (Marx & Herrnkind 1985), while larger lobsters forage solitarily at night but

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often share shelters during the day (Herrnkind et al. 1975; Eggleston & Lipcius 1992). The proximate causes for these shifts in group forming behavior were the focus of my dissertation (Ratchford 1997).

Among several species of spiny lobsters including *Panulirus interruptus* (Zimmer-Faust et al. 1985), *P. argus* (Ratchford & Eggleston 1998), and *Jasus edwardsii* (Butler et al. in press), the choice of diurnal shelters is influenced by odors emitted by conspecifics occupying the shelter. Variation in the release and receptivity to such conspecific odors explains these ontogenetic (Ratchford & Eggleston 1998) and diel shifts (Ratchford 1997) in sociality, at least among *P. argus*. Our studies demonstrate how variation in chemical communication could explain shifts in gregariousness on time scales of a single day and over the life of a lobster. On intermediate time scales, the reasons why lobsters do or do not share shelters are not explained by phenomena as simple as a change in the receptivity or release of a chemical. On these timescales, the ability of a lobster to detect and respond to the attractant must also be considered. The distance over which a lobster can sense and orient to an attractant will be influenced by the number and size of lobsters emitting the odor (Ratchford & Eggleston 1998), as well as by hydrodynamic parameters including the direction of flow, flow speed, bottom topography, and turbulence. The lability of the chemical cue is unknown. The process of aggregation of spiny lobsters at specific shelters apparently involves the return of some lobsters to the shelter they used the previous day, as well as the arrival of new lobsters to the shelter. Those that return are influenced by conspecific scents and by their experience with the area (Ratchford 1997). As a lobster locates more shelters within its home range, it may shift more frequently between these shelters. Eventually a lobster will use 3 to 4 shelters within a few hundred meters of each other (Herrnkind et al. 1975; Ratchford 1997). During nightly foraging excursions, some lobsters may move out of their home range (Herrnkind et al. 1975; Chittleborough 1974), and must locate a shelter in a new area. Other lobsters that have been disturbed at their shelter may not return (Herrnkind et al. 1975; Davs 1977). Lobsters that are the first to reside in a shelter probably provide cues for others, though this remains to be tested. The lobsters that are first to return may have used the shelter previously, though this needs to be tested as well. Certain physical attributes of the shelter, such as size, cover, and openings, influence shelter selection by spiny lobsters (Zimmer-Faust & Spanier 1987; Eggleston et al. 1990; Eggleston & Lipcius 1992) and presumably influence shelter fidelity and aggregation.

Group formation is an important behavior among social animals and the process of group formation among spiny lobsters is complex and not completely understood. Behavioral ecologists have emphasized the study of why animals form groups, but we are paying too little attention to the study of how animals form groups.

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A Graphical Comparison of Female Spiny Lobster Reproductive Potential Across Size Classes and Studies

From: R.D. Bertelsen

The relative contribution to the overall production of eggs by female lobsters of different size classes is dependant on the abundance of each size class of lobster, the propensity of each size class to produce eggs, and the number of eggs an individual in each size class will produce. A useful method to compare and contrast egg production of the different size classes was offered by Kanciruk and Herrnkind (1976). Briefly, the product of three parameters - the percentage of total lobster abundance, the percentage of lobsters bearing eggs, and the number of egg produced by an individual within a given size class - produces a weighted score of egg production for each size class. A constant is then derived to set one size class's score to 100. The constant is then applied to the other size classes and scores of all size classes can be compared.

In this article, I present a graphical representation using the Kanciruk and Herrnkind reproductive index to compare egg production of lobsters in different size classes. Two lines are produced. One line represents the abundance of each lobster size class divided by the total population (a population percentage). This is merely a plot of the first parameter used in the reproductive index. The second line represents the egg production of each size class divided by the total egg production (an egg production percentage). This is a plot of the second and third parameters given above. Size classes in which the population percentage is larger than the egg production percentage produce relatively fewer eggs ("underachievers") and those in which the egg production percentage exceeds the population percentage produce relatively many eggs ("overachievers").

Three graphs are shown (Figure 1). The first two graphs represent results from a three-year breeding-season study (March to September) of *Panulirus argus* in a large lobster sanctuary (Dry Tortugas) and a heavily fished area (Florida Keys). The third is from the Kanciruk and Herrnkind (1976) study conducted during October to November in the Bahamas. In all three cases, the smaller size classes tend to be "underachievers" and the larger size classes are "overachievers". By graphing the difference between egg production

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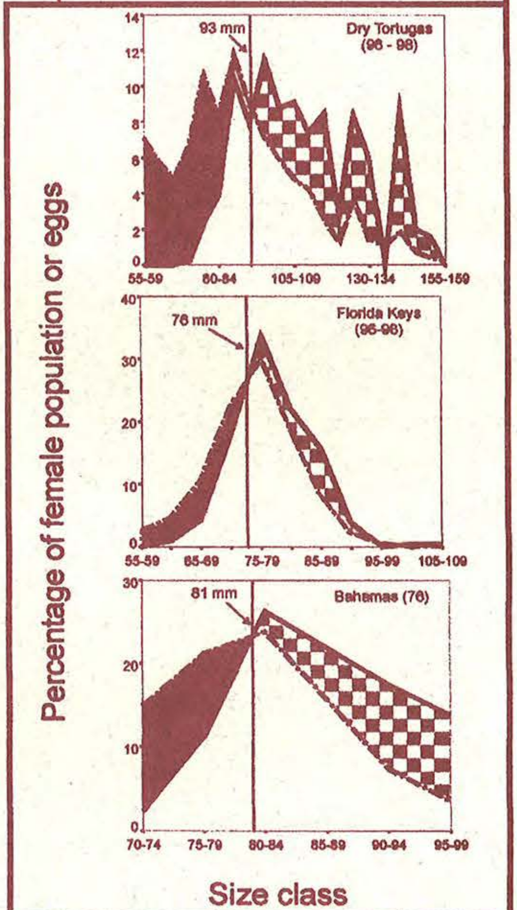

Figure 1: The percent contribution of lobsters of different sizes to the population (dashed line) and to egg production (solid line). Black area = "underachievement" in egg production; patterned area = "overachievement" in egg production.

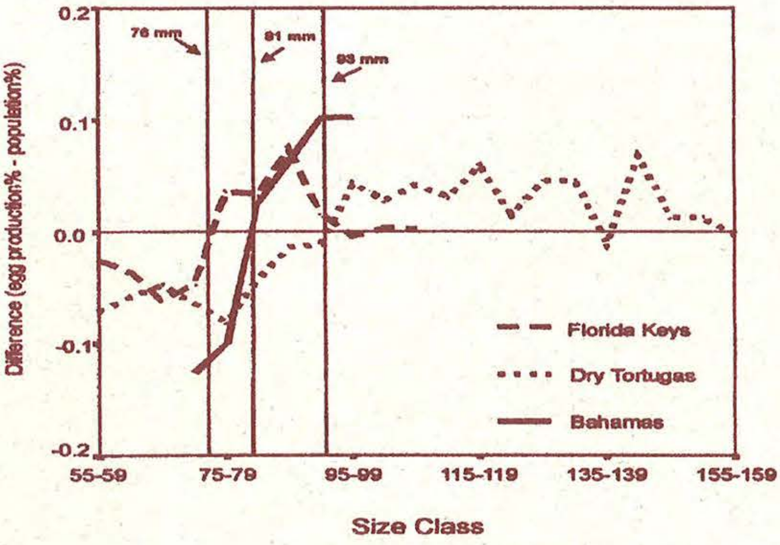

Figure 2: Egg production percentage minus lobster abundance percentage by size class. Areas of the line above zero indicate size classes that produce eggs in greater proportion than their relative abundance in the population.

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percentage from the population percentage (Figure 2), all three areas may be examined together. The size at which the smaller underachievers become overachievers is about 93 mm CL (carapace length) in the Dry Tortugas, 76 mm CL in the Florida Keys, and 81 mm CL in the Bahamas. Curiously, the crossover from underachievers occurs near the legal size limit in both the Florida and Bahamian fisheries (Florida Keys, 76 mm CL; Bahamas, 82 mm CL). Do you think this is a coincidence?

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FISHERIES & AQUACULTURE UPDATE

Mortalities of *Jasus edwardsii* Maintained in Captivity

From: Ben Diggles

My investigations began after reports of unusual mortalities from researchers studying mating in *Jasus edwardsii* and researchers keeping *J. edwardsii* juveniles collected from the wild. To date, four mortality syndromes have been recognized in our flow through system at Greta Point (Table 1).

Three of these, one bacterial and two fungal, occurred in juvenile lobsters. Of these, the internal fungus of the genus *Haliphthoros* appears a particularly important pathogen, as previously reported for juvenile *Homarus americanus* by Fisher *et al.* (1975). I have managed to grow this fungus in pure culture and am currently undertaking preliminary research into its taxonomy, growth, infectivity and control. More detailed study of this and the other diseases of the juveniles awaits future funding.

To date I have surveyed 40 newly collected *J. edwardsii* pueruli and a similar number of early juveniles from collectors, and none showed any sign of bacterial or fungal infection. This indicates that these agents are probably present in our system and act as opportunistic colonizers of stressed or damaged lobsters. Bacterial and fungal diseases reported in the literature on cultured crustaceans are usually linked to poor water quality or poor husbandry practices. I have noticed that regular cleaning of my tanks reduces the incidence of *Haliphthoros* infection, and I am currently investigating the effects of malachite green on juvenile lobsters and this fungus.

Perhaps the most interesting (and perplexing) disease is what we term "Turgid Lobster" syndrome, which affects large (>180 mm carapace length) adult *J. edwardsii* maintained in captivity. For reasons still a mystery, these animals swell up, and in many instances become so swollen that the membranes between the joints of the

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Table 1: Diseases observed in Jasus edwardsii at the Greta Point Laboratory, Wellington, NZ.

Syndrome	Gross signs	Causative agent	Onset and progression of disease	Prognosis / prevention
Fungal gill disease (external)	Cloudy, white, fuzzy appearance of gills.	Unidentified fungus, on outside of gill filaments.	Animals become lethargic, stop feeding. Fungus spreads throughout outside of gills in terminal cases and animal die before or during molt.	Prevention by maintenance of good water quality and/or periodic baths of malachite green*.
Fungal gill disease (internal in juveniles <30 mm carapace length)	Blackened areas on gills near base of walking legs.	*Haliphthoros* sp. fungus growing inside gill filaments.	Animals become lethargic, stop feeding. Increased number of ciliates (eg. *Epistylis* sp.), nematodes and other epibionts evident in and around necrotic gill lesions. Secondary bacterial infection may occur. Fungus spreads throughout inside of gills in terminal cases and animal die before or during molt.	Fatal disease in moderately infected animals. Some may recover from light infections if they survive moult. Usually associated with poor water quality and/or husbandry practices. Periodic malachite green baths may prevent spread of disease by killing fungal spores.
Systemic bacterial disease	Opaque tail muscle, blackened areas at tips of gills.	*Vibrio* sp. gram negative bacteria.	Animals become lethargic, stop feeding. Melanin deposition in gills due to cellular response against circulating bacteria. Tail muscle turns opaque in terminal cases.	Perhaps associated with poor water quality, or poor quality of food, or as a secondary infection concomitant with the presence of fungal agents.
Turgid lobster (Adults only)	Tissue swelling causing protrusion of soft tissue between joints of exoskeleton.	Unknown, possibly nutritional, physiological and/or bacterial involvement.	Animals become lethargic, drastic increase in hemolymph volume, causing swelling, 15 to 20% of animals die, others apparently recover.	Unknown.

* Note that lobsters infected by fungus are more susceptible to malachite green and heavily infected individuals may die.

exoskeleton and the abdomen protrude and the abdomen cannot be curled underneath in the usual fashion. A number of these animals recover but around 15 to 20% become immobile and die within a week or so of us first noticing the symptoms. The syndrome did not appear related to molt cycle or salinity fluctuations, but may be related to other water quality factors. For example, it seems that turgid lobsters are more common after algal blooms in Wellington Harbor from which our water is taken.

The swelling appears due to a large increase in hemolymph volume, and in fact if you prick the protruding membrane of a turgid lobster with a hypodermic needle, hemolymph spouts from the wound under pressure. The hemolymph appears slightly opaque, not as clear as in healthy lobsters, but retains its clotting ability and faint blue color. At first we thought it may be due to bacterial infection but no bacteria could be isolated from the hemolymph. Nevertheless, it may be that affected animals

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were suffering from minor bacterial infections, as histopathology of the digestive gland showed some bacteria were present in tubule lumens.

Examination of hemolymph smears from turgid lobsters showed no bacteria or ciliates, virtually a complete absence of mature granulocytes, and large numbers of cells that we first thought might be dinoflagellate-like protozoans. Transmission electron microscopy of those cells revealed they did not possess typical dinoflagellate features and in fact appeared more like non-typical host hemocytes. Cytochemical characterization of the cells suggested they were immature hemocytes, but why so many immature cells were circulating in the hemolymph of swollen lobsters remained a mystery. One theory is that it is related to accumulation of metals, such as cadmium, which are sometimes found in their mussel diet.

Atypically shaped granulocytes and greater proliferation of prohemocytes were observed by Victor (1993) in a crab *Paratelphusa hydrodromous* exposed to sub-lethal concentrations of cadmium chloride. Of course, a myriad of other factors could also be implicated in the syndrome. For example, nutritional factors affect both hemocyte numbers and hemolymph volume in lobsters (Stewart *et al.* 1967, Dall 1974). Our turgid lobsters had mussels available to eat but no record was kept of individual consumption, hence it is quite possible that starvation or inadequate nutrition may have triggered the syndrome.

Work on the turgid lobsters is presently on hold, but I welcome information or suggestions for research directions on this syndrome or the others mentioned.

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Commercial-scale Collections of Young Rock Lobster for Aquaculture

From: John Booth, Phil Davies, and Chris Zame

The quota trade-off arrangement in New Zealand in which, for every ton of quota retired from the commercial fishery for the red rock lobster (*Jasus edwardsii*) 40,000 pueruli and young settled juveniles can be taken locally, has led to commercial scale collections for ongrowing. Such large scale collections are now feasible because of the level of background knowledge about larval recruitment in this species, along with new information on settlement patterns and surfaces.

Settlement happens when shore-moving pueruli cease extensive forward swimming and take up residence on the substrate or in a collector. There is also often post-settlement migration in *J. edwardsii* so that, even in overnight checks of collectors, lobsters other than just newly-settled pueruli are caught. Settlement does not take place uniformly geographically or over time in New Zealand. Settlement is mainly at night and at any lunar phase, is usually seasonal, and levels of settlement can vary by an order of magnitude

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or more from year to year.

Collections have focused on the east coast of the North Island south of East Cape, the region of known high settlement. Experiments have been aimed mainly at developing simple, inexpensive, sturdy but effective devices which can be set in a wide range of coastal conditions. But at the same time we have been looking into cues for settlement and investigating more sophisticated collection techniques. Port Gisborne is the site at which most animals have been collected. There are spatial patterns in settlement within this harbour which, if they can be explained, could lead to better knowledge of the settlement process and what cues, if any, are important.

Monthly catches in the thousands are being achieved. This success may be seen as an opportunity for prospective harvesters of the same species in southern Australia and of other *Jasus* spp elsewhere.

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REQUESTS

Buddy, Can You Spare a Lobster?

From: Kari Lavalli

A group of us (Lavalli, Spanier, & colleagues) wish to initiate a study on the differences in shell structure among the lobster families (Palinuridae, Scyllaridae, and Nephropidae). In particular, we want to examine both cuticular setal distribution and types, and the internal pitting of the carapace. If anybody can send us specimens of the following species (see list below), we would be most appreciative. Carapace samples must be freeze-dried or stored in 70% ETOH; bits and pieces from legs, carapace, abdomenal sterni, uropods, telson, whole antennae or antennules, or mouthparts should be stored in 3% glutaraldehyde. Please send a diagram indicating the location on the body from which the pieces were taken. We hope to receive funding for this project in the coming year and may be able to reimburse contributers for their mailing and supply expenses.

The species we desire are:

Nephrops agassizii
Nephrops aculeata
Nephropsis atlantica
Nephropsis rosea
Homarinus capensis
Jasus frontalis
Jasus lalandi
Jasus edwardsii
Palinurus elephas
Palinurus mauritanicus
Panulirus laevicauda
Panulirus japonicus
Panulirus ornatus
Panulirus versicolor
Scyllarides deceptor
Scyllarides delfosi
Scyllarides aequinoctialis
Scyllarides latus
Scyllarides nodifer
Ibacus alticrenatus
Ibacus brucei
Ibacus ciliatus
Ibacus novemdentatus
Ibacus peronii
Scyllarus martensii
Scyllarus rugosus

Thanks in advance to all those who can help us on this project.

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ANNOUNCEMENTS

Sixth International Conference and Workshop On Lobster Biology and Management

Key West, Florida (USA)
September 10-15, 2000

INTERNATIONAL Lobster CONFERENCE & WORKSHOP KEY WEST 2000

Every three years, the *International Conference and Workshop on Lobster Biology and Management* brings together lobster scientists, fishery managers, and industry representatives from around the world for a week of scientific presentations, workshops, and discussions. The *Sixth International Conference and Workshop on Lobster Biology and Management* will be held at the Casa Marina Resort in Key West, Florida (USA) from September 10 - 15, 2000. Oral or poster presentations in English on any topic pertaining to lobsters (spiny, slipper, clawed, or scampi) that is of scientific or management interest will be considered. The Proceedings of the conference will be published as a single, regular issue of *Marine and Freshwater Research.* Along with the scientific sessions at the conference, there will also be ample opportunity for participants and accompanying persons to enjoy the many attractions available in Key West and Florida. If you would like more information, visit our web site at: *http://www.odu.edu/~biology/lobsters/index.html* or contact:

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ERRATUM

In the last issue (Vol. 11, No. 1) we erronously omitted portions of the captions to tables 2 and 3 in the lead article by Stan Cobb and Bruce Phillips. Here are those captions in their entirety. Our apologies. - Eds.

Table 2: Publications directly resulting from the International Lobster Workshops.
Table 3: Citation analysis of five papers resulting from the 1977 and 1985 workshops.

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Contact any Editor about submission of articles. Send change of address requests to Peter Lawton.

Comments on final editing and production should be sent to Mark Butler.

ANNOUNCEMENTS

Third International Conference on Shellfish Restoration

The International Conferences on Shellfish Restoration have recognised the major role in marine production of the estuarine and shelf areas of the world and the pressure being placed on them. After two meetings in the US, the Third International Conference on Shellfish Restoration - Europe '99 not only takes on a European dimension but also includes for the first time non-molluscan shellfish, including lobsters.

The meeting will be held 29 September to 2 October 1999 at Jury's Hotel, Cork, Ireland with the emphasis on the merging of science and management. Contributions are welcomed from both academic and industry sectors. Of particular interest will be the review of the European lobster ranching programme and examination of the role of artificial reefs in enhancing lobster populations.

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June 1999

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