RESEARCH NEWS

Lobsters use Repetitive Loading to Open Molluscan Prey

From: Karen T. Lee

Large clawed decapods usually consume bivalves as part of their natural diet (Elner and Campbell, 1987). A wide variety of opening tactics have been described for crabs, including direct crushing, chipping, peeling, biting and prying (for review see Lau, 1987) whereas lobsters (and some of the larger crabs) have only a few opening tactics; relying on brute strength rather than finesse.

One of the tactics employed by crabs is repetitive loading of bivalve prey, up to 2 pulses per minute (Boulding and Labarbera, 1986). This repetitive loading causes failure of bivalve shells at forces lower than predicted static strength and allows crabs to crush larger bivalves than would otherwise be possible.

Elner Campbell (1981) suggested that the American Lobster, *Homarus americanus*, may not employ repetitive loading as a prey crushing technique, or that if it does, it is mechanically different from the technique employed by crabs. Our results, from a series of laboratory experiments, suggest that *Homarus* can use repetitive loading to open large molluscan prey.

Behavioral Experiments

As part of my dissertation work (Northeastern University Marine Science Center, Nahant, MA in the laboratory of Dr. Joseph Ayers) on stereotypy in *Homarus* food handling behavior. I videotaped starved lobsters feeding on blue mussels (*Mytilus edulis*) for up to three hours per trial, analyzed the tapes via stop-frame analysis and described the behaviors used and their timing.

During the experiments, lobsters consumed mussels successfully in 1/3 of the trials. In another 1/3 of the trials lobsters attempted to crush mussels repeatedly without success (in one trial as many as 241 times in under three hours). Even with the three hour time limit, unsuccessful trials lasted longer than successful ones, though not significantly (mean total trial duration successful: 243± 365.5 secs.; unsuccessful: 8414.13± 2379.97 secs.; Mann-Whitney U test; z=.1852, p=0.064). As expected, mussels not consumed in three hours were significantly larger (compared to crusher length) than those consumed, though there is some overlap between the ranges (successful: relative prey length 0.357± 0.023; range 0.34-0.4; for unsuccessful trials: 0.495±0.147; range=0.38-0.71; Mann-Whitney U test: z=2.507, p=0.0122). Thus, in these experiments, lobsters attempted to crush large mussels repeatedly for much longer than it took to crush smaller mussels.

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RECENT EVENTS

Phyllosoma Reared to Settlement

From: John Booth

A team headed by Dr Len Tong at the National Institute of Water and Atmospheric Research's Aquaculture Centre, Mahanga Bay, Wellington, New Zealand has reared *Jasus edwardsii* to settlement. The eggs hatched in October 1994, and after 23 instars and 416 days, one metamorphosed to the puerulus stage.

A novel upwelling culture system is thought to have been important in the high survival to Stage VIII. Ongoing work aims to improve rearing systems and diets and thereby increase survival and reduce moult intervals, particularly in the later stages.

CONTINUED ON PAGE 12

RESEARCH NEWS

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Physiological experiments

To more closely examine feeding behavior, I used electromyography (emg) to monitor movement of the chela closer muscle in freely-behaving lobsters during crushing behavior; defined as the lobster placing the mussel into the crusher claw. Analysis revealed that during this behavior, the crusher claw often closed up to fifteen times in a single crush attempt. Thus, not only did the lobster place the mussel into the crusher claw many times during a feeding trial, it also exerted force on the mussel several times during a single crush attempt. The bursts of activity from the closer muscle are relatively short (ranging from 0.1-3.9 secs) and frequent (as many as 15 bursts in under 40 seconds). (This differs from the timing of repetitive loading seen in crabs, which crush only 2 times per minute.)

Biomechanics experiments

To look at the relationship between crushing force and breaking strength, three sets of experiments were performed: first, the static strength of mussels was tested, by loading them with weights until the mussels cracked; second, the force produced by reflexive closing of the crusher claw was measured using a pressure transducer attached to a fluid-filled piece of tubing (Microswitch Corp.). Lobsters were removed from the water and the tube placed into the crusher claw, inducing reflexive crushing. The results from the first two experiments were used to calculate the maximum sized mussel that a lobster could crush. The third experiment tested this prediction. Separately housed lobsters were provided 5 mussels at a time and checked each day to see which mussels had been consumed. Increasingly large mussels were provided in successive trials until mussels remained unconsumed for 5 days.

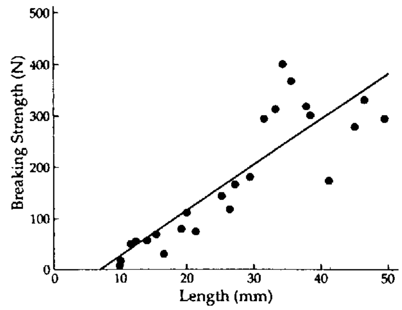

Figure 1a: Relationship between mussel breaking strength and mussel length

As expected, larger mussels have higher breaking strengths. The rather crude method of testing mussel strength showed a clear relationship between mussel length and breaking strength (Fig. 1a). The results of the force measurements of claws were equally predictable. Lobsters with longer crusher claws are stronger (Fig. 1b).

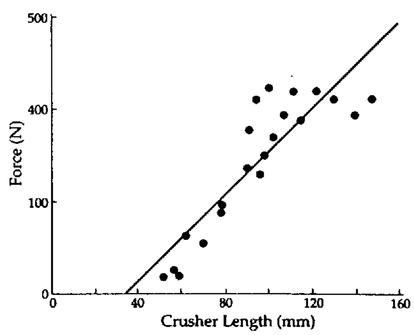

Figure 1b: Relationship of maximum reflexive crushing force to crushed length

These regression equations predicted that lobsters should only be able to break mussels up to 25% of crusher length if using outright crushing. Results from the feeding experiments, on the other hand, showed that lobsters were able to consume mussels much larger than 25% of crusher length when given time to do so (Fig. 1c). As expected, lobsters with larger claws consumed larger mussels.

An additional piece of evidence emerged from these experiments. Temporal parameters of reflexive crushing resemble those of the emg recordings. The mean burst duration from the emg recordings of crusher closer muscle (0.846 ± 0.067 secs) was not significantly different from the mean duration of reflexive crushes from the force transducer (1.051 ± 0.053); Mann-Whitney U test: z+-1.536, p=.1245).

It seems clear, from the available behavioral, physiological, and mechanical evidence, that lobsters can use repetitive loading techniques to break large molluscan prey. The loading is different from that used by crabs; crabs use longer, slower

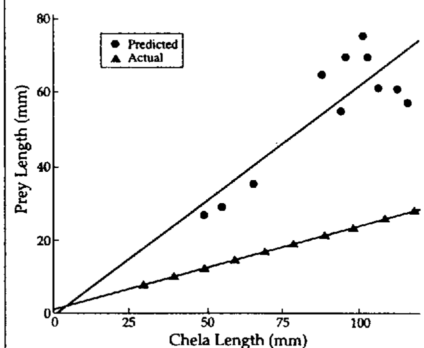

Figure 1c: Predicted maximun size consumed vs actual

force applications. Results suggest that lobsters can break larger mussels than would be predicted if they were only using brute force. More detailed examination of the food handling behavior of *Homarus americanus* should uncover further complexities not previously described.

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Test of a Method for Telling the Age and Stage of a Rock Lobster

From: David MacMillan, Mark Thomas and Tobi Stuart

Most readers of The Lobster Newsletter will know of the contribution of Professor Mike Laverack to our understanding of crustacean receptors and of the untimely death of he and his wife when the helicopter in which they were traveling crashed during a field trip to Australia's Great Barrier Reef in 1993. At the time of his death we were about to start a series of experiments based on a hypothesis of his that grew out of an interest in the number of neurons in crustaceans.

The number of motor neurons and interneurons is determined early in development and the number of sensory neurons increases in various ways depending on the sense organ or modality involved, some reaching the adult number early, others growing throughout life (Laverack, 1987, 1988). Mike surmised that the genetic instructions for growing the nervous system and related structures, which are internal, might differ from those responsible for developing the external integument. If this were the case, the number of neuronal sensors in some external sense organs might reflect the age or moult stage of the animal irrespective of the size of the integument on which they are situated. In other words, neurally derived structures might, in some cases, grow at a steady rate different from that of the integument, which is clearly subject to considerable variation. If there were external receptors that developed in this way, their size and number on the surface could provide a non-invasive means of determining the age or stage of the animal. In support of this idea, Mike produced some preliminary evidence on the rate of increase in the number of elements in the Cuticular Articulated Peg Organ of *Homarus gammarus*. Cuticular Articulate Pegs (CAPs) are the peg-like elements of proprioceptive arrays situated close to the articulating membranes of crabs, lobsters and other macrurans (Laverack, 1978). CAP organs provide the animal with information about joint angles by signaling how many of their pegs are deflected by the articulating membrane of the joint during flexion and extension (Oakley and Macmillan, 1980).

We are now midway through a project comparing the growth curves for various body parameters and the number of CAPs in the CAP organs of *Jasus edwardsii* to see whether CAPs could be used to give an independent estimate of the age of this animal. The attraction of a CAP measurement is that in mature animals it could be carried out without special equipment by any observer.

We are studying integumental growth and CAP development by collecting the moult cases of individual animals as they pass through consecutive developmental stages. The animals have been cultured from puerulus stage larvae, housed individually in a recirculating seawater system and checked daily for moults. So we have, in the moult cases, a complete history of the animal's growth and CAP organ development since the puerulus stage. We would be pleased to discuss making some of these specimens available to other researchers who could derive information from them. The morphology and number of CAPs in the organ monitoring the mero-carpopodite joints of the 4th and 5th legs has been recorded by examining the moult cases in the Scanning Electron Microscope and capturing the images on computer for measurement and graphical analysis.

The number of CAPs in the CAP organs of early juvenile *Jasus* appears to increase in a linear fashion with developmental stage and age. Carapace length, as a measure of integumental growth, also increases linearly. This suggests that we are still in the early juvenile stage of development where growth of the integument and nervous system are expected to run parallel. As the animals continue to age, their integument growth will tail off. Whether or not the CAP organs will continue to develop at a rate independent of size, is still unclear. To maximize the difference in the size of animals of the same age we recently divided our animals into three groups: normal temperature, lowered temperature and raised temperature. This will improve our chances of seeing whether the program responsible for the development of the CAP organs is independent of the external size of the animal or not within a reasonable experimental time frame.

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RESEARCH NEWS

Predators of Young Released European Lobsters

From: G.I. van der Meeren

Releases of hatchery-reared juvenile *Homarus gammarus* L. were made in west Norway between 1988 and 1994 by personnel of the Institute of Marine Research. Releases since 1990 were part of the government sea ranching program, PUSH. Between 9,800 and 39,700 juveniles (10-40 mm CL) were released each year (van der Meeren 1994). Transportation and release techniques were described in van der Meeren and Uglem (1993). We identified predators of the releases by diving and by fishing with trammel and hoop nets.

Table 1

Species known to prey on released juvenile lobster (<40 mm CL) based on underwater video recordings (rec), recovery of tags from the predators gut (tag), or through recovery of juvenile lobster remnants in the gut (obs).

Crustacea	*Homarus gammarus L. (European lobster)*	*tag*
	Carcinus maenas L. (common shore crab)	*rec*
	Cancer pagurus L. (edible crab)	*tag*
Fish	*Gadus morhua L. (cod)*	*tag*
	Anguilla anguilla L. (eel)	*obs*
	Labrus bergylta Ascanius (Ballan wrasse)	*obs/rec/tag*
	Labrus bimaculatus L. (cuckoo wrasse)	*obs/tag*
	Symphodus melops L. (corkwing)	*obs/tag*
	Taurulus bubalis Eurphrasen (sea scorpion)	*tag*
	Platichtys flesus (flounder)	*tag*

Prior to 1990, the release of lobsters by divers, onto the sea bed each August without acclimation to ambient water temperature caused problems. Ten percent of the juvenile lobsters swam rapidly up and down in the water column like a jig, while the remainder lay immobile on the sea bed, resulting in about 10% mortality by predatory labrid fish in the first few hours (van der Meeren 1991). From 1990, lobsters were acclimatized for at least 30 min in ambient water before release at the surface of shallow (<10m) waters. Releases took place on calm days in November and between February and May (van der Meeren 1994), at a density of one lobster m^{-1} of shore. Acclimatized lobsters either sank slowly or swam steadily to the sea bed; finding shelter within one hour; no predation was observed.

Lobsters released since 1990 have been tagged with Bergman-Jefferts magnetic microwire tags (van de Meeren and Uglem 1993). These tags can been detected in the gut of predators following lobster digestion. We were sure these fish (180-350 mm long) were indeed the direct lobster predator as they were generally too small to have eaten prey sufficiently large to have preyed on our released lobsters. The microwire tags removed from the fish provided information on age and size of the lobster.

Predators of small crustacea and mussels - birds, mammals, and fish - are all potential predators of juvenile lobsters. Animals in Norwegian waters which are known predators of lobster juveniles up to 40 mm CL are listed in Table 1. Table 2 lists species which have attacked our tagged juveniles, but have not eaten them. All species, and there are probably others, are common in coastal waters of Norway and must be regarded as a threat to young lobsters. We are studying, year-round, fish and decapod species in various lobster habitats and the survival of lobsters released into these habitats; the ranking of the most effective predators will result.

Table 2.

Species seen in video recordings attacking tagged juvenile lobsters (<40 mm CL).

Coelenterates	*Tealia felina L. (sea anemone)*
Fish	*Micrenophrys lileborgi Collet (Norway bullhead)*
Birds	*Larus argentatus L. (common gull)*

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Killing Lobsters Humanely: Call for Discussion

From: Paul Breen

What's a humane way to kill a lobster? In New Zealand, recently, we had a short-lived media frenzy when a local politician claimed that chopping the tail off a lobster was "barbaric".

Whether or not you think this a subject important enough to spend time on likely depends on your country's views on the topic; nevertheless, for some of us it's going to be a re-occurring problem. Animal rights people are beginning to consider fishes and invertebrates, so for lobster fisheries the issue has the potential to damage markets. For example, animal ethics committees are starting to work their way down to crustaceans in codes of practice that affect all researchers.

There seems to be a great lack of definitive information. In researching a response from our Minister, I came across a variety of essentially speculative arguments, but nothing very solid. One school of thought is that the lobster brain is too primitive to register pain. I scanned a lot of abstracts from recent lobster neurological work, and couldn't find anything that even seemed relevant to this level of question.

A colleague sent me a copy of Gunter's (1961) paper, suggesting that slowly raising the water temperature to about 40°C killed crabs and lobsters "quickly, without pain". The "without pain" step referred to in this and other arguments I came across is inferred from gross behaviour. Gunter said the animals "die quickly and easily without showing distress". Conversely, we tend to think that tail-flipping and leg-scrabbling reflect distress when lobsters are boiled (as down here) or placed in fresh water. The movements seen after "tailing" could reflect distress or could be entirely reflexive.

A University of Maine report (I've only seen indirect references to it) used "twitching" as a measure of distress in comparing various methods of killing lobster.

There's an obvious danger in using behavior to reflect "distress", or lack of a particular behavior to reflect lack of "distress", at least without supporting evidence. How do we know what the behavior really signifies?

This concern flows on to the potential for replacing the "common" method of killing with a less humane one. The University of Maine study found that 'hypnotizing' lobsters before cooking (rubbing them while holding them head down; thought to be more humane than straight cooking) actually **increased** the twitching time during cooking.

Is biological science able to develop a coherent and consistent opinion on this issue? What experimental evidence is available from the people who work inside lobsters and write those intimidating papers? In the absence of any such information, and under the assumption that lobsters do feel pain, how do we proceed towards a credible scientific opinion on whether specific methods are cruel or not?

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FISHERIES AND AQUACULTURE UPDATE

Experimental trap-fishing for Natal deep-water spiny lobster (*Palinurus delagoae)* off South Africa in 1994 and 1995.

From: Johan Groeneveld

The deep-water spiny lobster, *Palinurus delagoae* is endemic to the south-east African coast where it occurs off northern Mozambique, southern Madagascar and eastern South Africa. It inhabits both rocky- and organically-rich muddy substrata at depths of 100 - 600 m where it forms a substantial by-catch in a multispecies crustacean trawl fishery, operating off South Africa and Mozambique since the early 1960's (Groeneveld and Melville-Smith 1995). Experimental trap-fishing of *P. delagoae* in South African waters was introduced in 1994, after a commercial fishing concern had shown interest in exploiting the resource by this method. A number of local fishing concerns operate a similar long-line trap-fishery on spiny lobster, *Palinurus gilchristi*, off the south coast. Suitable fishing vessels, equipment and expertise were thus available for our winter-month experiments, when south coast vessels are normally laid up.

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These vessels could fish east coast rocky areas that are inaccessible to trawl nets.

The area needing surveying extended southwards along the Kwazulu-Natal coast, from the Mozambique border at 27°S to 32°S, the southernmost latitude of which *P. delagoae* distribution. In this area, between the depth interval 75 and 425 m the area was subdivided by depth and latitude, and in 1994 long-lines with traps were set roughly parallel to the coast at 75, 150, 250, 300, 350 and 400 m depths along transects separated by 15-25'. Size composition and *cpue* data were collected by researchers aboard the vessels; the data were used to establish the size distribution and availability to traps of *P. delagoae*. Depth had the strongest influence on size distribution, mean carapace length increasing as depth decreased from 400 to 150 m, and based on this, a long term inshore migration pattern of *P. delagoae* was suggested by Cockcroft et al. (In press). Relative abundances of 446.8 $g.trap^{-1}$ for *P. delagoae* and 144.9 $g.trap^{-1}$ for the slipper lobster (*Scyllarides elisabethae*) by-catch indicated that a commercial trap fishery would be effective (Groeneveld *et al.* In press).

It was decided a second experiment would improve the abundance estimates and provide another annual data point for the *cpue* and size composition time series. Information on the distribution and abundance of *P. delagoae*, the bottom topography of the shelf, and the influence of the current regime on fishing gear prompted some modifications to the survey strategy before the second survey experiment got underway in 1995. Changes included an experimental TAC of 104 tons whole mass (including both *P. delagoae* and *S. elisabethae*), the development of an extensive grid system which covered the shelf according to depth and latitude, and the elimination of both the shallowest depth interval (50 - 112.5 m) and the stations south of 31°S, as little was caught in these areas in 1994. Each grid was sampled with two long-lines before the commercial vessel could fish its TAC. Concurrently, 5000 *P. delagoae* were tagged for growth and migration studies.

Concentrations of *P. delagoae* could be identified clearly by depth and area after the 1995 survey. Commercial densities of large, *P. delagoae* (0.5 - 3kg/lobster) occurred in two distinct areas, from Cape Vidal (28°S) to Richards Bay (29°S) in the northern half of the experimental areas, and south of Durban (30° - 20°42'S) in the southern half. These two areas were separated by a stretch of muddy sea-bottom on which the light, barrel-shaped plastic traps caught little. North of Cape Vidal and extending to Mozambique, a marine reserve that stretches 3 nm seawards from the coast restricted trapping to the deepest grids (> 350 m), where small lobsters (mostly <0.25 kg/lobster) were caught. Catches in all areas compared well with 1994. The best catches in 1994 were made in 250 - 400 m depth (Cockcroft *et al.* In press) compared to 200 - 375 m in 1995.

Number of *S. elisabethae* made up 32.6% of trap catches in 1995 compared to 31.2% in 1994. However, when *P. delagoae* was specifically targeted at its preferred depth and area, catches of *S. elisabethae* declined to 17.1%, presumably because it prefers a slightly different depth and softer muddier bottom type than *P. delagoae* does.

A sustainable commercial fishery envisaged for the east coast region would face a number of practical problems. The southward-bound Agulhas current overflows the fishing grounds and in both annual surveys it stopped effective fishing early in September buoy submergence for extended periods. Strong currents presented few problems between June (when the experiments started) and August. Taking this into account, an earlier start to the annual fishing season would be advisable, though it must be synchronized

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with the breeding season, previously (Berry 1973, Kondritsky 1976) shown to fall off sharply in May.

In southern-most latitudes, trapping was made hazardous by a steep bottom gradient and strong currents. In this region, the distributional ranges of *P. delagoae* and *P. gilchristi* overlapped, with decreasing numbers of *P. delagoae* in deep water (> 250 m), which corresponded to increasing numbers of *P. gilchristi* in slightly shallower water. Harsh bottom and current conditions here are expected to serve as a natural barrier between the two fisheries.

P. delagoae in South African waters, is currently subjected to exploitation by traps and trawling. In fact, the importance of *P. delagoae* in trawls has increased significantly in the past five years; it has been targeted more often owing to decreased catches of prawns (Groeneveld and Melville-Smith 1995). Largest annual lobster catch by trawlers was 33.4 tons in 1993. Pending the results of the research surveys, an additional directed trap-fishery taking in the order of 100 tons of *P. delagoae* annually is envisaged for the east coast, which would make this the third most important spiny lobster fishery off South Africa, after the fisheries for West Coast lobster *Jasus lalandii* and South Coast lobster *P. gilchristii.*

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RESEARCH NEWS

Distribution of lobster larvae in the NW Coral Sea

From: Roland Pitcher, Darren Dennis, Tim Skewes, Chris Evans and Phillip Polon

In 1990, scientists from Papua New Guinea and Australia surveyed the deep waters of the Gulf of Papua and the far northern Great Barrier Reef, using a manned submersible, with the aim of documenting the distribution of breeding populations of the tropical spiny lobsters *Panulirus ornatus* (Lobs. Newsl. 1991, 4(2): 8-9). Very few lobsters were seen in the Gulf of Papua, despite the well documented annual breeding migrations across it; however, high densities were seen on deep (40-100 m) relic reefs on the edge of the far northern Great Barrier Reef. Some lobsters were also present on adjacent shallow coral reefs, but the size-distribution and sex ratio of these differed from that of the deeper reefs. The extent of these breeding grounds still needs to be confirmed and this is the aim of fieldwork planned for February 1996.

Questions also remain regarding larval transport and which, if any, of the known breeding populations may be a source of recruitment to the Torres Strait fishery - this knowledge will delimit the boundaries of the stock. The transport pathways of the ornate rock lobster larvae from the breeding grounds to Torres Strait are virtually unknown, but possible trajectories of larvae from the eastern Gulf of Papua breeding grounds were studied during 1990, by CSIRO personnel plotting the movements of satellite tracked drifters. These, and similar drifters released by AIMS, indicated the presence of a clockwise gyre in the far north-western Coral Sea (Fig. 1). The gyre has the potential to mix larvae from both the far north-eastern Queensland coast and Gulf of Papua breeding grounds and retain them adjacent to Torres Strait until the SE trade winds could return them to Torres Strait between June and September each year. Until now this explanation had been merely a hypothesis as there was no information on the distribution and abundance of larvae relative to these major currents. Further, the actual trajectories may be far more complex given that lobster larvae are capable of considerable diurnal migrations and active swimming.

To address the question of larval transport, CSIRO personal sampled several areas in the north-western Coral Sea during 2 weeks in May, 1995 using their research vessel, *F.R.V. Southern Surveyor.* The cruise dates were chosen to maximize the chances of sampling lobster larvae in the Coral Sea. Breeding finishes in March and settlement in Torres Strait begins in June, thus the sampling window is narrow. Larvae were sampled day and night, at several depths, and over two moon phases using a large mouthed (70m^2) pelagic trawl net, leased from the New Zealand Ministry of Agriculture and Fisheries.

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The net was towed for 2 1/2 hrs between approximately 500 m and 5 m, stratified into five depths by a multiple opening/closing cod-end system, on each of six shots in each of areas 1-6 (Areas 7-11 were not completed due to mechanical problems with the vessel) located in the north-western Coral Sea (Fig. 1). More than 2,700 phyllosomas and 125 pueruli were caught - most adjacent to the Great Barrier Reef, with catches decreasing eastwards across the Coral Sea. A wide range of sizes and developmental stages of several different species of phyllosomas were caught - one phyllosoma was approximately 85 mm total length. Most of the pueruli were of one form. About 30 of these were returned live to the Cleveland laboratory where they were cultured and identified as *P. ornatus* after moulting into coloured post-pueruli. We suspect the majority of phyllosomas caught were *P. ornatus* as well, however, detailed examination and identification of all phyllosomas sampled, has yet to be completed.

Plans to complete this research with another *Southern Surveyor* cruise in May 1997, will enhance our understanding of larval ecology, in particular their vertical and horizontal distribution, growth, larval retention areas and sinks, possible recruitment mechanisms, and stock boundaries for resource management.

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Influence of Sea Temperature on the Abundance of Spiny Lobsters at Bermuda

From: C.R. Evans, A.M. Lockwood and A.J. Evans

The fishery for spiny lobster on the Bermuda Platform produced annual yields of about 30,000 Bermuda lobsters, *Panulirus argus* (Latreille), and about 25,000 Guinea chick (spotted or star) lobsters, *Panulirus guttatus* (Latreille), during 1975-1989. *P. guttatus* is restricted to the reef-crest line and adjacent reefs, whereas *P. argus* is found over the Island shelf; animals in the inshore harbours and sounds constitute a protected *P. argus* nursery area. Development of *P. argus* phyllosoma larvae from hatching to metamorphosis around Bermuda takes approximately one year. Post-settlement growth to legal-size (>92mm CL) takes about three years.

There is an association between sea surface temperature, inshore abundance of *Homarus americanus* and catch fluctuation in the Maine (USA) fishery. Dow (1980) illustrated a linear positive correlation of annual *H. americanus* landings (y) on annual sea surface temperature (x) during 1957-1968, with the following function: $y = -30.8 + 1.54x$. Lellis and Russell (1990), in an aquarium-based study, developed a quadratic model for the growth and survival of postlarval *P. argus*. The basal metabolic rate of the postlarvae increased with increasing temperature, but food uptake did not increase to maintain body growth at high temperatures. Survival had a quadratic response to temperature also; at higher temperatures this was related to mortality at a ecdysis. Survival, moult increment and moult frequency of postlarval *P. argus* were each correlated with temperature by quadratic regression functions, with an optimum of 29-30°C for survival and growth at this stage (Lellis & Russell 1990).

Trends of inter-annual changes of both CPUE and sea temperature influenced abundance, but not in a linear way (Evans & Evans, 1995). Graphical analyses indicated empirical quadratic associations between industry CPUE in the *P. argus* and *P.* guttatus fisheries and the annual average sea temperature at Hamilton Harbour. Inter-annual change in the combined (*P. argus-P. guttatus* spiny lobster stock abundance level also suggested an association of abundance with the average sea temperature of the Bermuda Platform (Evans & Evans 1995).

Extension of the Lellis and Russell (1990) model to explain industry CPUE and yield of *P. argus* and *P. guttatus* at Bermuda (for 1975-1989) formed the basis of a paper by Evans *et al.* 1995), who hypothesized that temperature is important in determining the timing and level of annual recruitment to the fishery. Their analyses indicates that CPUE and yield of *P. argus* and *P. guttatus* were each associated, by quadratic expressions, with the annual average sea temperature of the Bermuda Platform (Evans *et al*, 1995). The CPUE of *P. argus* by lobster season (September-March) was associated with the average sea temperature (at Hamilton Harbour) of the year (January through December) in which the lobster season began, but this was not the case for calendar year CPUE (Fig. 1). Evans *et al* (1995) concluded that catchability was unlikely to be the underlying cause of the associations observed.

In summary, growth and survival of late juvenile *P. argus* and *P. guttatus* into the fishable stock at Bermuda is controlled in a quadratic fashion chiefly by sea temperature with a six month response lag to physiological stimuli and constraints. The optimum annual sea temperature for survival and growth of late juvenile phase *P. argus* into the fishery is 23.6 +/- SE 0.2°C, the comparable optimum temperature for *P.*

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guttatus recruitment is 24.1 +/- SE 0.1° C (Evans et al, 1995).

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Spiny Lobsters Sex: Is Bigger Always Better?

From: Alistair MacDiarmid, Rob Stewart and Mark Butler

Does mate size affect mating success and fertilization rates in spiny lobsters? This is an important question, both for captive breeding programs and also for the wild fishery where intense fishing reduces the abundance and mean size of males relative to females. We are part way through a program of field and laboratory studies designed to examine the effects of mate size on mating success, fertilization rates and fecundity in two species, *Jasus edwardsii* in New Zealand and *Panulirus argus* in Florida.

The relative size of both male and female may impose important physical, physiological and behavioral constraints on the success of courting, copulation and subsequent fertilization rates. Spiny lobsters copulate sternum to sternum after rising to a vertical embrace. Small individuals may not be able to physically accomplish this with a larger mate. If small males have a limited sperm supply then the consequences for a female could be reduced rates of fertilization or a reluctance to mate at all. In *Jasus* species the spermatophore is short lived (hours) and starts to quickly disintegrate; hence, females immediately extrude their one annual clutch immediately after mating. Thus in *Jasus* females may show greater discrimination in choice of mates than in *Palinurus* and *Panulirus* species where the spermatophore is long-lived (days to months), increasing the potential for multiple mating by females to ensure that enough sperm is available to fertilize all eggs.

We are taking advantage of striking differences in the size composition of lobster populations in marine reserves and adjacent fished areas to make inferences about the effects of size on mating. Four adjacent populations *J. edwardsii* in northern New Zealand, two protected for at least a decade and two heavily fished, were surveyed during the peak of mating in June 1995 to determine lobster abundance, size frequency, sex ratio, female size at onset of maturity and courting activity. Egg clutches from a size range of females were subsequently collected from each population to estimate fertilization rates and realized fecundity. These await analysis. We observed 57 courting pairs; in all but two cases the male was larger than the female by between 10-90 mm CL. In two cases the couples were of equal size. Courting males were always larger than the mean size of mature males in each population.

During a sabbatical visit to New Zealand by Mark Butler, a laboratory experiment was set up at NIWA facilities at Great Point to test for the effects of mate size on courting, egg-bearing, fertilization rates and fecundity. Three levels of male size, covering the size range of mature males, were introduced to 5 premoult, unmated females (over the size range of mature females) in each of 5 replicate tanks per treatment. They were monitored daily for moulting, courting, and egg bearing from March-August 1995. Sixty days after mating, whole egg clutches were removed from mated females for later determination of fertilization rates and total egg number. These await analysis. Results of the experiment so far indicate that very large males, 185-210 mm CL, have a high probability of mating with all-sized females (overall mating probability = 0.92), whereas small males, 90-100 mm CL, are most successful with smaller females and overall mated with only 50% of the females available to them. Intermediate sized males had intermediate success. Inexperience, sperm depletion, female choice and behavioral inhibition by larger females are several reasons why small males were less successful than large males. These will be explored in another series of experiments in the 1996 breeding season.

Similar field work and laboratory experiments will be conducted on *P. argus* in Florida, as part of a reciprocal visit by MacDiarmid, in March-July 1996.

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RESEARCH NEWS

Why is the Spiny Lobster Jasus Absent from the Chilean Coast?

From: Dave Pollock

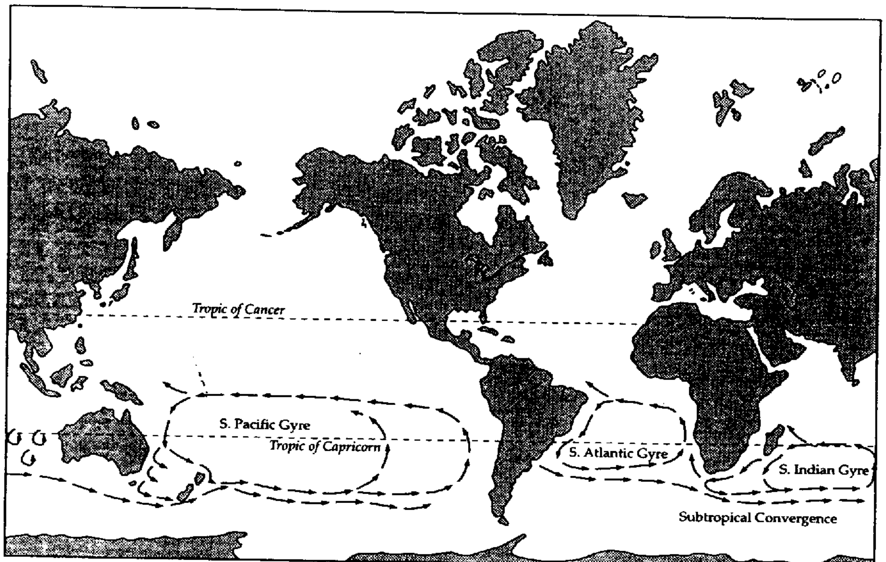

Figure 1

Species of the coolwater spiny lobster genus, *Jasus*, have successfully colonized a number of island and mainland habitats at latitudes north of the subtropical convergence, in all three ocean basins of the southern hemisphere (Fig. 1).

Despite apparently ideal environmental conditions on the coast of Chile, with adequate rocky substrate, kelp beds and suitable food supplies in the form of mussels and other molluscs, crustaceans, sea urchins, polychaetes, etc., this coastline is devoid of spiny lobsters. However, some 700 km offshore, at approx. 34°S latitude, the Juan Fernandez islands support a population of the large-growing species *Jasus frontalis*. The waters here, being oceanic in nature, are less productive than the cooler, upwelled waters along the coast of Chile, and it remains an interesting puzzle as to why the mainland coast of Chile has apparently never been colonized by *J. frontalis* or any other *Jasus*, whose phyllosoma larvae are in the currents of the open ocean.

One possible explanation is that some larvae of *J. frontalis* do reach the coast of Chile, but do not metamorphose and settle, because of a lack of appropriate environmental cues to trigger metamorphosis. A close analogy exists in the case of the insular species *J. tristani* of the South Atlantic, whose larvae drift from Tristan da Cunha and Gough islands towards the south-western coast of southern Africa, but which never appear to metamorphose and settle there (Pollock, 1990; 1991). Instead, a continental species, *J. lalandii* occurs abundantly along the west coast of southern Africa, between latitudes of approx. 25° to 35°S. This is an upwelling region, similar in environmental characteristics to the coast of Chile at similar latitudes.

Why has a continental-type species [like *J. lalandii* or *J. edwardsii* (S. Australia, Tasmania, New Zealand)] never colonized the Chilean coast?

One possible answer to this may lie in the characteristics of ocean current circulation off the coast of Chile. Several *Jasus* species appear to rely on large-scale ocean gyres to act as dispersal and return mechanisms for their long-lived phyllosoma larvae. Ex-

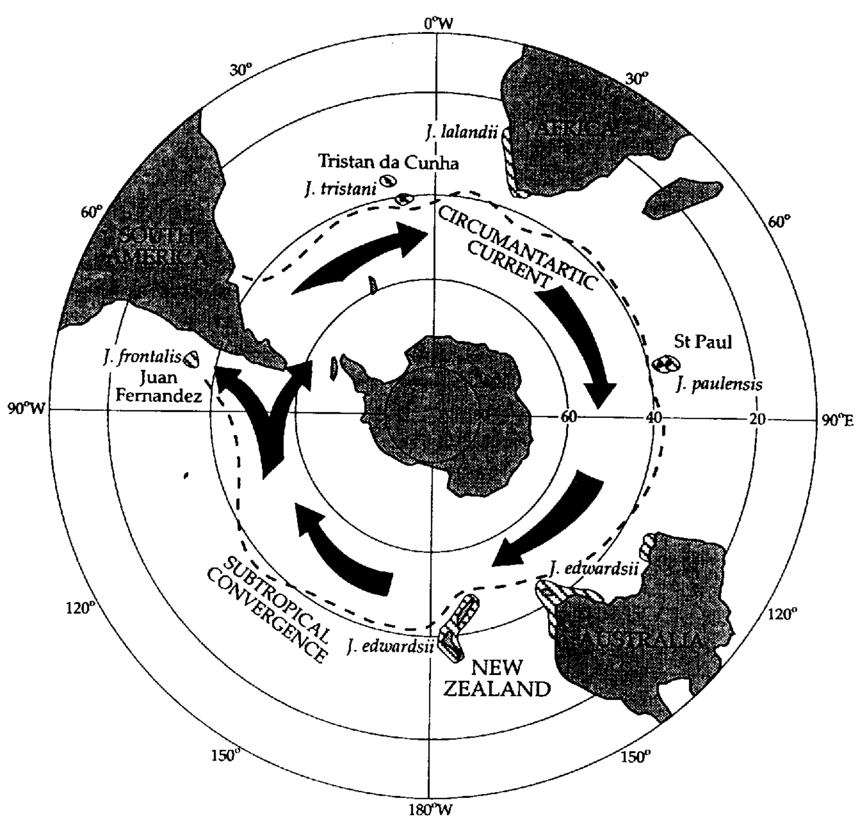

Figure 2

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amples are *J. tristani* and *J. lalandii* whose larvae appear to be transported within the large scale motion of the S. Atlantic gyre. Larvae of the South Indian Ocean species *J. paulensis*, from St Paul and New Amsterdam islands, probably also rely for their dispersal and return on the gyre current system of the South Indian Ocean, which circulates via the coast of southern Madagascar, the east coast of southern Africa (Agulhas current) and retroflects south of the Cape to return eastward, flowing past St Paul and New Amsterdam at approx. 38ºS, to recirculate back into the South Indian Equatorial current at about 70º to 80ºE (Fig. 2).

Coastal waters of Chile are derived from the Humboldt current, which originates from subantarctic waters south of the subtropical convergence, and flows north along the western seaboard of South America (Fig. 1). Coastal waters are modified and cooled further by upwelling as they move northwards to form the Peru coastal current. However, the islands of Juan Fernandez lie well offshore of the old Humboldt current, being situated within the eastern margin of the South Pacific anticyclonic gyre system, which circulates between the islands to as far west as the coasts of Australia and New Zealand (Fig. 2). Presumably, larvae of *J. frontalis* may return to their native island habitat after months or years of drifting in the south Pacific gyral current. In contrast, the Chilean coast appears to be isolated from the Pacific gyral current per se, owing to the presence of the subantarctic Humboldt current and upwelling zone along the coast. Lack of a suitable large-scale current system for dispersal and return of phyllosoma larvae may thus have precluded successful colonization and maintenance of recruitment by *Jasus* species along the coast of Chile. Although other explanations are possible, eg. a coastal Chilean *Jasus* taxa could have become extinct as a result of disease, predation or competition in times gone by, the ideas on larval recruitment presented here may provide a useful insight into the importance of large scale oceanographic systems for the maintenance of *Jasus* populations in the ocean basins of the southern hemisphere.

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Offshore Movement of the Spiny Lobster *Jasus edwardsii*

From: Shane Kelly

The offshore movement of spiny lobster, *Jasus edwardsii*, have been examined over the last two years in the Cape Rodney to Okakari Point Marine Reserve in northern New Zealand. When the marine reserve was established in 1975, the seaward boundary was set at 800m from shore, thereby providing a buffer zone for the reef system, which extends out 300m. The substrate around the boundary consists of sand flats, dominated by various bivalves, whelks, and small crabs, all of which are potential prey items for *J. edwardsii*. Fishers dredging for scallops around the reserve boundary in the mid 1980s brought up lobsters; when lobster traps were set, substantial numbers of lobsters were caught. In subsequent years large numbers of lobsters have been taken annually from around the reserve boundary.

A tagging program was established to determine the origin of lobsters caught offshore, and to determine whether they move inshore. This study confirmed that lobsters were originating from within the reserve, and that lobsters tagged beyond the boundary return to the reserve reef system. The timing of offshore movement was found to vary for different size and sex components of the population. Large males (over 130mm CL) were found in summer, following the main male ecdysis period, and in winter after the mating season. Both ecdysis (McKoy and Esterman 1981) and mating (A. MacDiarmid pers. com.) are energetically expensive processes, during which feeding rates are reduced, so offshore movement may be associated with increased foraging intensity to rebuild metabolic reserves.

During the day these animals remain on the sand flats where they form defensive aggregations, rather than returning to the reef for shelter. Up to 40 animals have been observed in circular aggregations, however single lobsters have also been found on the sand during the same period. The lobsters face outwards with their antennae pointing upright. If disturbed they arc their antennae over their backs, and often move aggressively towards the threat. Though a single individual within an aggregation can respond aggressively to a threat, such as the presence of a diver. In places with limited ground cover, such as horse mussel (*Atrina zealandica*) beds, they may lie against the substrate with antennae held flat on the sand, enabling them to blend into the background. Although they have not been observed buried, a thin layer of sand commonly collects on their backs, providing an effective form of camouflage.

McKoy and Leachman (1982) found similar aggregations of ovigerous females offshore in winter, close to the end of their egg bearing season, and proposed a movement away from the reef,

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Although Prof. Kittaka and his team have grown several species of spiny lobster (including *J. edwardsii*) to settlement at Sanriku, Japan, it is understood that this is the first time out of Japan that a spiny lobster has been cultured from egg to settlement.

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Please send change of address to John Pringle.

RECENT EVENTS

A new Species of *Jasus* has been found

From: John Booth and Rick Webber

It is almost 110 years since the last new *Jasus* species was reported. Admittedly, *novaehollandiae* and *J. frontalis* were not separated from *J. lalandii* until 1963 (and *J. novaehollandiae* has since been found to be indistinguishable from *J. edwardsii*), however, the *Jasus tristani* we know today from Tristan da Cunha and the Vema Seamount in the South Atlantic Ocean was first described in 1888 by Bate (as *Palinostus lalandii*). We now have a further species of *Jasus*, the name and full description for which we expect to give in the December 1995 issue of the *New Zealand Journal of Marine and Freshwater Research.*

The *lalandii* group of *Jasus* (which includes all species of *Jasus* except *J. verreauxi*) is subdivided into the *lalandii* subgroup (*J. edwardsii* in Australasia and *J. lalandii* from southern Africa) and the *frontalis* subgroup (*J. paulensis* from the south Indian Ocean, *J. frontalis* in eastern South Pacific, and *J. tristani* from the South Atlantic). The subdivision is based on the shape of the carapace spines, the shape of the transverse groove before the posterior margin of the carapace and particularly the level of "squamal" sculpturing on the dorsal abdomen (see George and Kensler 1970).

About 12,000 specimens of the new *Jasus* were taken by a commercial vessel, from a seamount in the central South Pacific Ocean earlier this year. The species belongs to the *frontalis* subgroup and is most similar to *J. frontalis* from Juan Fernandez and Desventuradas Island off Chile - but it is clearly quite different because it has almost no abdominal squamal sculpturing.

The new species is the first to occur exclusively on a non-emergent seamount; all other *Jasus* species occur both along the coasts of islands or continents as well as on seamounts. The lobsters were taken from the top of the seamount at 140 m down to a depth of 180 m.

The duration of the phyllosoma larval stage of *Jasus* spp, where it is known, is among the longest for any palinurid - around a year or more. This gives opportunity for wide larval dispersal. The discovery of this species in an area between the waters occupied by *J. edwardsii* and by *J. frontalis* means that reaching an understanding of *Jasus* larval recruitment processes in the South Pacific Ocean has become even more of a challenge.

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AMUSEMENTS

Lobsters enter Debate on Political Future of Canada

From: H. Powles

Jacques Parizeau, Prime Minister of Québec, was reported to have told European ambassadors in a confidential meeting that the people of Québec, once they had voted for sovereignty, would be like lobsters in a pot. Those in the know will recall the long-standing debate over whether Québec should separate from Canada—Québeckers will vote in a referendum on this late in 1995. Parizeau's statement was immediately denied and some theorized that releasing it was a federalist ploy to discredit the sovereigntist movement. Journalists, freed from the necessities of reporting real news by Canada's summer recess from politics, theorized as to whether he might have meant that the people of Québec would be like lobsters in a pot of boiling water or like lobsters caught in a trap (pot). Fully appreciating the howls of outrage from federalist (keep Canada one) and sovereigntist (free Québec from Canada) camps over "l'affaire homard" would require more background in recent Canadian constitutional politics than most reasonable people would want to cultivate. However, the event did inspire political cartoonists to let their imaginations roam on a lobster theme and some of the results are presented here.

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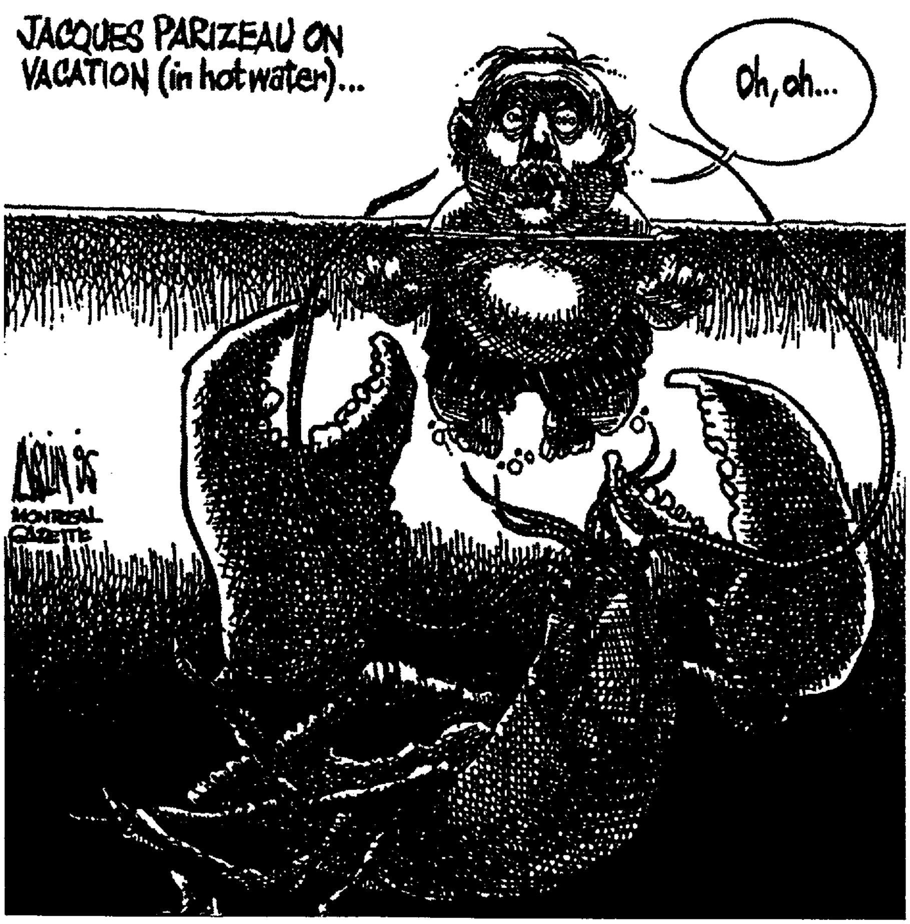

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into areas of greater water movement, in order to facilitate rapid dispersal of larvae. This may also be the case here, however females are often caught in these areas with either early stage eggs or having already hatched their eggs. This suggests that another factor, such as foraging, may trigger these movements. Gut content analysis supports this conclusion, and has revealed that offshore females forage on a variety of items including hermit crabs, bivalves, and fish scraps. In addition, large numbers of females readily enter baited traps set around the seaward boundary. Immature female and small male lobsters are commonly in the same trap with ovigerous females. While some overlap in the timing of offshore movement of large and small males does occur, there appears to be considerable temporal separation between these groups. No males less than 130mm CL have been observed in male aggregations. We thus hypothesize that males undergo an ontogenetic shift in habitat utilization.

In the coming year I plan to make greater use of the highly successful acoustic tag to track movement of individual lobsters. Acoustic tags revealed the offshore movement of males in winter, and have enabled divers to quickly relocate tagged individuals and their associated aggregations. It is hoped the acoustic tag will allow the temporal and spatial aspects of movement by various components of the lobster population to be fully described.

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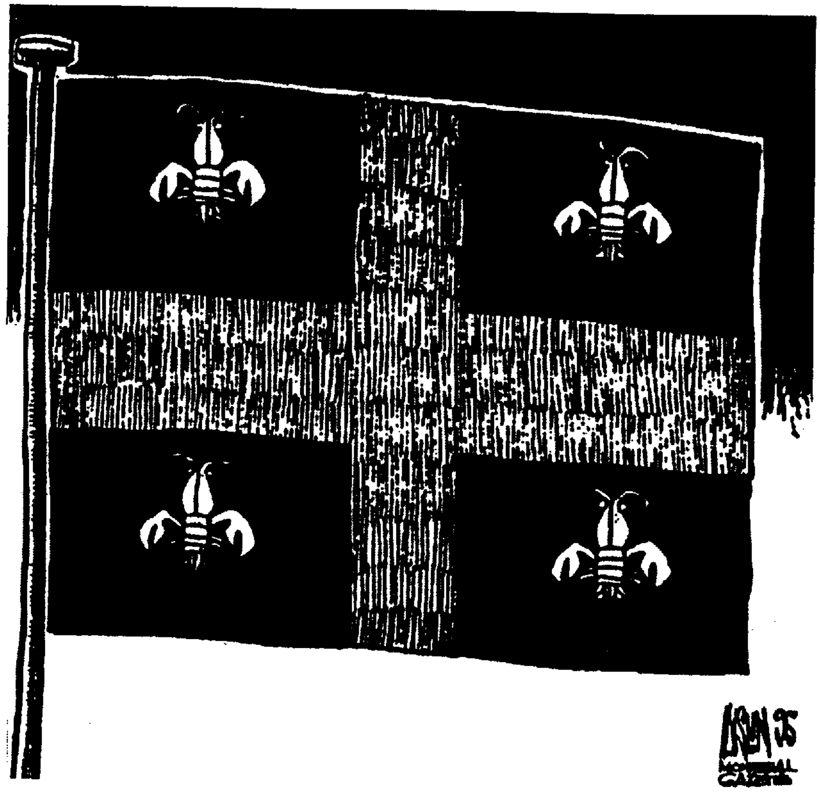

Lobsters replace the fleur-de-lis on the Quebec Flag

"After a Yes, the people of Québec will be like lobsters" (Parizeau). The lobster's questions are word-plays which would take some time to explain--it is basically woundering about its fate.

M. Pariezeau was on holiday in Provence when his supposed remarks were reported - what if he was served a lobster?

"We're just shaking the lobster trap" (ie. rattling his cage)

ANNOUNCEMENTS

From: Paul MacNab

Researchers, fishers and Parks Canada have been investigating the potential role of closed areas in the Newfoundland lobster fishery. Any reports, publications or information from similar projects would be greatly appreciated. Please contact: (address above)

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ANNOUNCEMENTS

New Zealand 1997 Lobster Meeting Update

In the issue we enclose the first notice and preregistration form for the *Fifth International Conference and Workshop on Lobster Biology and Management* to be held in Queenstown, New Zealand during 9-14 February 1997.

The notice asks for provisional titles for papers and also lists the topics for workshops where less formal presentations and discussions will take place (see July 1995 *Lobster Newsletter*).

The preregistration form asks you to indicate the standard of accommodation you require. Please deal with this expeditiously - accommodation has to be booked at least 3 months before the meeting - by early November 1996.

You may have noticed new addresses and contact numbers. Nothing is ever easy - New Zealand's old "MAF Fisheries" no longer exists. We spiny lobster workers (Paul Breen, Alistair MacDiarmid, John Booth) are now employed by the National Institute of Water and Atmospheric Research Ltd (NIWA), a government-owned research organization. This has led to changes in postal and e-mail addresses and in phone numbers - although the old ones will work for some time yet. NIWA is now the coordinator of the 1997 Lobster Meeting.

For further information, please contact:

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