Cooperative research between Japan and New Zealand advances understanding of early life history of spiny lobsters

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SUMMARY Cooperative research between Japan and New Zealand on Jasus edwardsii and Sagmariasus verreauxi has led to significant advances in world understanding of palinurid reproduction and early life history and in palinurid aquaculture. Field discoveries showed that the puerulus stage is essentially non feeding and that there are extensive post-settlement migrations. Both species have been cultured to settlement in both countries. The usefulness of upwellers, presence of microalgae in the culture medium, and use of mussel as food were principal outcomes from phyllosoma culture work in Japan. S. verreauxi is the palinurid closest to being commercially cultured. The international collaboration, along with individual endeavour, has led to many primary papers, and has culminated in several overview book chapters.

KEY WORDS: international cooperation, palinurid, phyllosoma, puerulus, recruitment, spiny lobster

INTRODUCTION

Research undertaken cooperatively between Japan and New Zealand over the past 17 years on two of New Zealand’s spiny lobsters, Jasus edwardsii and Sagmariasus verreauxi, has led to significant advances in world understanding of palinurid reproduction and early life history. Through these joint initiatives, as well as through its own endeavours, Japan leads the development of palinurid aquaculture, being the first country to culture phyllosoma larvae to settlement. New Zealand was the second (and only other) nation to accomplish this.

New Zealand waters contain four species of palinurid (spiny or rock lobster), but only two are common and commercial, J. edwardsii and S. verreauxi (formerly Jasus verreauxi1). Both are also found in Australia. In 1984, Japanese and New Zealand scientists began exchange visits, along with coordinated individual and joint field and laboratory studies, aimed at improving understanding of reproduction and early life history in these two species. For Japan, the motivation to work with temperate water spiny lobsters from the Southern Hemisphere lay in the cultural significance of spiny lobsters, particularly the Japanese Panulirus japonicus,2 landings of which, although steady, were not capable of much expansion. There is no palinurid fishery in northeast Japan and there was the possibility of growing a cool water species there, either for release into the wild as pueruli to establish a fishery (after careful determination of ecological and other impacts), or for the production of pueruli for land-based aquaculture. The similar latitudinal extent of both countries, each centered near the 40° parallel although in opposite hemispheres, together with overlapping water temperatures and compatible habitats, meant such a plan was feasible. The incentive for New Zealand to participate was the opportunity to better understand larval and settlement processes in its most important inshore fishery, and to be at the forefront of progress towards palinurid aquaculture.

The association between Japan and New Zealand was an evolving, somewhat unstructured one that flourished because the research aims of the participants – countries and scientists – overlapped. Directions for research were often modified as new results came to hand. This approach came about largely because of the manner in which the work was funded. The Japanese scientists received most of their funds from their Ministry of Education, Culture and Science. The New Zealanders as government employees had planned objectives to meet, but were able to cooperate where theirs coincided with those of the Japanese. All this took place against a background of very different languages and traditions, sometimes challenging but always a rewarding experience.
Although Japan has engaged in cooperative research into spiny lobsters with many countries, the focus here is on its relationships with New Zealand. The contacts and outcomes took several forms, from exchange visits by scientists to joint symposia. This review documents the nature, extent, outcomes, and significance of this research.

INITIAL CONTACTS

The first association between Japan and New Zealand on spiny lobster research occurred when Professor Jiro Kittaka of Kitasato University, Sanriku, Iwate Prefecture visited New Zealand in December 1984. Working under a Grant-in-Aid for Overseas Scientific Survey from the Japanese Ministry of Education, Culture and Science, the visit, which also took in Australia, was an opportunity to determine the feasibility of working jointly with New Zealand to develop an understanding of the early life history characteristics of their local, cool water spiny lobsters. Mature J. edwardsii were subsequently airfreighted to Sanriku. A larger group of scientists (Drs J. Kittaka, T. Saisho, Y. Hayakawa, Y. Nimura, and R. Kado) visited New Zealand in November 1985 to study the distribution of Jasus and the flora and fauna and oceanographic conditions of its habitat.

INVESTIGATIONS IN NEW ZEALAND

Three extended visits to New Zealand were made between 1989 and 1991 by Japanese scientists (variously by those above, but also Drs S. Nishida and H. Sekiguchi) to study, in particular, J. edwardsii settlement behaviour. By the last visit, however, the focus had shifted towards S. verreauxi. Castlepoint, in the southeast of the North Island, was a suitable place to intensively study J. edwardsii settlement patterns in relation to the environment because of its sheltered aspect. Puerulus collectors already in place were supplemented by others so as to monitor daily settlement over about 5 weeks. The results showed, the first time for any palinurid, that significant post-settlement migration can take place. Daily rates of settlement could not be correlated with any of the environmental variables measured (water temperature, salinity, wind speed and direction, moon phase), suggesting that factors most important in determining settlement patterns act offshore.

At the same time, tank experiments were set up at Castlepoint to observe the behaviour of J. edwardsii pueruli by stage of development. Forward swimming was observed in unpigmented pueruli, but not among pigmented ones, suggesting a neurological change in pueruli in advance of the loss of the large pleopods at the forthcoming moult. During the day pueruli often buried themselves in the sand, the first such observation for Jasus.

Newly-settled J. edwardsii pueruli were also available for other studies, including investigations into tolerances to different temperatures and salinities. Pueruli from oceanic waters with temperatures around 17°C did not tolerate without acclimatization temperatures above 26°C or salinities below 26‰. The statocyst, the organ that detects spatial position, was found to be different in form to that in all other decapods.

The change in emphasis to S. verreauxi resulted from the larval culture work in Japan (described below) which showed that the phyllosomas of this species were more hardy and appeared to be better candidates for aquaculture than those of all other species, and because the juveniles were also fast growing.

CONCURRENT STUDIES IN JAPAN

Beginning in 1984, mature J. edwardsii and S. verreauxi, along with puerulus and first instar juvenile J. edwardsii, were regularly airfreighted to Japan in order to establish breeding stocks at Sanriku and also to provide young lobsters for investigations into growth and feeding. Both species were available at such places as Tokyo’s Tsukiji Fish Market, exported live from the New Zealand commercial fishery, but dedicated consignments meant that the origin of the lobsters was certain.

J. edwardsii was only the second palinurid to be cultured to the puerulus stage. There are 17 phyllosoma instars, the species taking about 300 days to reach metamorphosis. Cultured at 18.5°C, the puerulus stage lasted 19 days. But the numbers of J. edwardsii cultured to puerulus were low; there was much greater success with S. verreauxi, for which 168 pueruli were cultured in 1990-91. The number of instars in S. verreauxi was the same as for J. edwardsii, but on average larval development took only about 200 days.

Several important issues concerning phyllosoma culture and behaviour resulted from this larval culture work – later corroborated in the culture of other palinurids. First, larval culture time and final larval size tended to be significantly shorter among cultured larvae than those from the wild. Using microalgae, principally to control water quality, is advantageous in culturing
phyllsomas. Third, using upwellers for larvae older than mid-stage is appropriate, if not essential. Phyllsomas use a characteristic spiralling and looping swimming pattern\(^2\) that leads to more extensive vertical than horizontal movements, which the upwellers allow. Last, mussel gonad is a convenient and nutritious food, particularly for later phyllsoma stages,\(^2,13\) although other foods can also be used.\(^6,13\)

*\(S. \text{ verreauxi}\) phyllsomas differ from those of *\(J. \text{ edwardsii}\) in having an exopod on the fifth pereopod as well as one on the third maxillipeds.\(^5\)* Nevertheless these are closely related palinurids and experimental comparisons of their nutritional needs with those of more distant relatives were made. For example, early stage larvae of both *\(S. \text{ verreauxi}\) and *\(J. \text{ edwardsii}\) were less tolerant of low food availability than *\(Homarus \text{ americanus}\) larvae of similar age.\(^14\)

A shortage of late stage phyllsomas of *\(J. \text{ edwardsii}\) for experimental work in Japan was the main prompt for Drs Nishida and Sekiguchi to join part of a cruise on the Ministry of Agriculture and Fisheries’ research vessel *James Cook* in June 1988 sampling the distribution and abundance of phyllsomas off the east coast of New Zealand. Phyllsomas were maintained alive on board, and some were subsequently sent to Japan where one survived to the puerulus stage.\(^15\) This was the first time that phyllsomas from the wild had been cultured after long air transport. *James Cook* sampling also provided material for the description of the morphology and distribution of the seven types of integumental organ on the final stage phyllsoma of *\(J. \text{ edwardsii}\)\(^5\) and for a description of the most advanced phyllsoma of *\(Puerulus \text{ angulatus}\) so far reported.\(^17\)

No feeding by pueruli had been observed in the New Zealand investigations so the question arose, was the puerulus a non-feeding stage? This was studied in several ways for both *\(J. \text{ edwardsii}\) and *\(S. \text{ verreauxi})*; observations of the behaviour of cultured pueruli;\(^5,6\) histological examination of preserved, recently-settled pueruli;\(^7,8\) and morphological examination of the mouthparts of the late stage phyllsoma, puerulus, and first instar juvenile.\(^9\) These studies all pointed to pueruli not feeding, or if any feeding was taking place, to it being confined to small, soft materials. They also indicated that the hepatopancreas was the primary site of energy storage and supply.

Professor Kittaka found wet weight food conversion ratios for small juvenile *\(J. \text{ edwardsii}\) fed mussels to be between 5:1 (at 12\(°\)C) and 7:1 (at 20\(°\)C).\(^10\) Growth rates of juveniles of both *\(J. \text{ edwardsii}\) and *\(S. \text{ verreauxi}\) were determined, *\(S. \text{ verreauxi}\) growing particularly fast and reaching 26 mm orbital carapace length after 160 days at 15-18\(°\)C (and seven moults) on a diet of mussels.

Stocks of mature lobsters in hand meant that details of the breeding cycles of *\(J. \text{ edwardsii}\) and *\(S. \text{ verreauxi}\) sent to Japan could be determined. Both lobster species had within two years of arrival in Japan undergone a phase shift of about 6 months in their breeding and egg-bearing cycles from those in New Zealand.\(^13,18\)

**SYMPOSIA AND OVERVIEWS**

The Symposium on Ecology and Production of Spiny Lobsters was held in Japan, at Sanriku, in mid 1986. The dispersal, settlement, and movements of *\(J. \text{ edwardsii}\) and *\(S. \text{ verreauxi}\) in New Zealand were addressed, along with the oceanographic conditions and flora and fauna of the *\(Jasus\) habitat.\(^5\)

The next time the Japanese and New Zealand scientists met was at the Fourth International Workshop on Lobster Biology and Management in July 1993, again held at Sanriku and convened by Professor Kittaka. The proceedings of the meeting were published in four issues of *Crustaceana*, six of the 45 papers dealing specifically with *\(J. \text{ edwardsii}\) or *\(S. \text{ verreauxi}\).

The Nemuro Workshop on Oceans and Fisheries ’95 Spiny and Clawed Lobsters, organised by Professor Kittaka and held in November 1995, provided the next opportunity to gather. The proceedings were published in a dedicated issue of *Bulletin of Marine Science* - 61(1), with three of the 14 papers dealing specifically with New Zealand lobsters. Particularly significant was the description of the full larval development of *\(S. \text{ verreauxi}\).\(^5\) The significance of long-distance migrations by benthic-phase lobsters in the larval recruitment mechanisms of *\(J. \text{ edwardsii}\) and *\(S. \text{ verreauxi}\) was also defined.\(^19\)

At the Fifth International Conference and Workshop on Lobster Biology and Management, held in Queenstown, New Zealand in February 1997, 15 of the 62 papers were on *\(J. \text{ edwardsii}\) or *\(S. \text{ verreauxi})*, several of them emanating from the Japan-New Zealand association.

The cooperation between Japan and New Zealand into spiny lobster research culminated in joint review chapters in the 2000 publication *Spiny lobsters: Fisheries and Culture*. These chapters updated those in the 1994 book *Spiny lobster Management*, providing a prospectus for palinurid aquaculture\(^20\) and reviews of spiny lobster juvenile-
growout\(^{10}\) and breeding biology.\(^{16}\) The cooperative work was also important to the chapter on larval rearing.

THE PRESENT SITUATION

*S. verreauxi* larvae have now been hatched in Japan from adults previously cultured from the egg there, so this is the palinurid closest to having its life cycle completely closed. Both *J. edwardsii* and *S. verreauxi* have now also been cultured to settlement, in small numbers, in New Zealand,\(^{21,22}\) incorporating several of the techniques developed in Japan, particularly the use of mussel gonad as food for the later stages. *S. verreauxi* is presently a focus of endeavours in New Zealand and Australia to culture spiny lobsters commercially, and remains the palinurid species closest to commercial production. In Japan, the experience gained working with *J. edwardsii* and *S. verreauxi* is being applied to the culture of *P. japonicus* and *Palinurus elephas*.

CONCLUSIONS

Japan and New Zealand are world leaders in their understanding of reproduction and early life histories of palinurids and in their progress towards commercial aquaculture of palinurids. This position has been reached through many years of cooperation and at times joint research. The scene is now well set for expansion of global knowledge in these areas.

REFERENCES