Population dynamics of Scyllarid lobsters of the genus *Thenus* spp. on the Queensland (Australia) east coast
I. Assessing the effects of tagging

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Abstract

The effect of different combinations of tagging and release methods was examined on the survival, moulting, growth increment and recapture rates of slipper lobsters *Thenus* spp. on the Queensland (Australia) east coast using generalised linear modelling methods. Laboratory experiments indicated that while tagging is unlikely to significantly affect the survival rate or growth increments of lobsters, it is likely to lower the incidence of moulting. In the field, recapture rates of tagged lobsters increased markedly by applying an antibiotic/antifungal ointment to the tag wound and by minimising the length of time lobsters were held on board prior to release. Recapture rates for *Thenus orientalis* declined by about 0.5\% for every hour lobsters were held on board prior to release, even though they were kept in aerated seawater. About twice as many male *T. orientalis* were recaptured compared to females. Reasons for this may be related to size differences between the sexes and how the fishers valued the rewards for different size classes. The size of the T-bar anchor tag affected recapture rates of *Thenus indicus*; recapture rates of lobsters tagged with small tags were about 33\% higher than those with large tags. Two different methods of release were also compared; surface release and bottom cage release. Recapture rates of large lobsters and those that were held on board for several hours prior to release were improved by using the bottom cage method. However, under some conditions, the cage may lower recapture rates relative to the surface release method, possibly because of increased stress and trauma from crowding in the cage. For both species, growth increments of recaptured lobsters increased with the period at liberty and declined with increasing lobster size. Females had significantly larger growth increments than males.

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1. Introduction

Little research has been carried out on the population dynamics of lobsters from the family Scyllaridae (slipper lobsters) compared with the more valuable Palinuridae (spiny rock lobsters) and Nephropidae (clawed lobsters). Of the seven genera constituting the Scyllaridae, *Thenus* is the most economically important (Jones, 1988). In Australia, logbook reports indicate that about 600–1000 t of slipper lobsters, mostly *Thenus* spp., are caught annually, mainly as byproduct of prawn and scallop trawling. Most of the catch (400–840 t) is landed in Queensland and is composed of two species (Jones, 1988; Kailola...
et al., 1993); *Thenus orientalis* (reef or sand bug) and a smaller species *Thenus indicus* (mud bug). About 100 t of *Thenus* spp. are reported from Australia’s Northern Prawn Fishery (Sachse and Robins, 1997), while 110–120 t of *Ibacus* spp. are caught in the more temperate waters of New South Wales (Kennelly, per. comm., New South Wales Fisheries). Landings of less than 20 t of *Thenus* spp. and *Ibacus* spp. are reported in Western Australia annually.

In Queensland, fishers neither differentiate between *T. orientalis* and *T. indicus* in their logbook records, nor are they differentiated in market place. However, there are slight differences in their taxonomy and distribution. *T. orientalis* is caught by fishers targeting scallops and king prawn at depths of 40–50 m, while *T. indicus* is generally caught while targeting endeavour, banana and tiger prawns in nearshore waters at depths of 10–30 m (Jones, 1988). As byproduct, the range of management alternatives for the lobsters is limited as changes to fishing effort, mesh size or closures would affect catches of the more valuable targeted species. The only management measure that was implemented for many years was the prohibition on possession of egg-bearing females. In the early 1990s, concern by fishers over declining catches and possible overfishing prompted further management intervention. This resulted in an interim minimum legal size (MLS) of 62 mm carapace width (CW) for both species which has recently been increased to 75 mm CW. These minimum sizes were designed mainly to meet marketing requirements rather than to achieve an optimum fishery strategy based on biological data.

The main objectives of the present study were to measure growth and mortality rates of *T. orientalis* and *T. indicus* from Queensland coastal waters by tag-recapture experiments, and to evaluate the MLS using yield-per-recruit type analyses. However, prior to undertaking such an assessment, it is important to understand how the parameter estimates might be affected by the tagging process. For example, growth rates derived from tag-recapture data are likely to be biased if tagging inhibits molting or affects growth increments. Similarly, it is important to quantify the rate of tag shedding as this affects the mortality rate estimates (Hilborn and Walters, 1992) used in yield-per-recruit analyses. While tagging effects have been investigated for other lobsters (Brown and Caputi, 1983; Trendall, 1989; Moriyasu et al., 1995), relatively little is known about Scyllarids. The few relevant studies that have been undertaken include those of Jones (1988), who tagged and released 948 *T. orientalis* on the Queensland coast and Spanier and Barshaw (1993), who investigated the effects of different tag types on the survival, molting and retention in the Mediterranean slipper lobster, *Scyllarides latus* in laboratory aquaria.

This paper therefore assesses the effects of tagging on *T. orientalis* and *T. indicus* from the Queensland coast. Hypotheses pertaining to the effects of different tagging and release methods on survival, incidence of molting, growth increment, tag shedding and recapture rates were tested and improved methods for future studies were identified.

2. Materials and methods

Tagging effects were examined in *T. orientalis* held in laboratory aquaria and in both species released and recaptured at sea. Because of inadequate numbers and the long distances required to transport live *T. indicus*, we were unable to use this species in the laboratory experiments.

2.1. Laboratory experiment

Tagging effects were examined for a total of 80 *T. orientalis* held simultaneously in four 5 t aquaria for approximately 4 months (119 days; 15 October 1993–11 February 1994). The lobsters were captured by commercial trawler operators, transported to the laboratory and acclimatised in aquaria for 1 week prior to the experiment. Two different sizes of tags [small (TBF-2) and large (TBA-1) T-bar anchor tags produced by Hallprint, Australia] were compared. Tags were soaked in an antiseptic solution (Hibitane) prior to being inserted in the dorsal surface between the cephalothorax and abdomen, and slightly off-centre to avoid the gut and gonads. Each aquarium was allocated eight lobsters tagged with large tags, eight with small tags and four lobsters that were not tagged (controls).

The effect of an antibiotic/antifungal ointment applied to the tag wound, as a measure of reducing post-tagging infection and mortality, was also assessed. The ointment was prepared in the laboratory
and consisted of a mixture of 2 g of oxytetracycline (antibiotic) and 30 g of Conofite (Trademark) ointment which contains the antifungal miconazole nitrate at a concentration of 20 mg/g. Half of the lobsters with large tags and half with small tags had the ointment applied to the tag wound at the time of tagging. All treatments were applied equally across aquaria. Response variables examined were the rates of survival, moulting, tag loss and growth increment. While measures of CW are suitable for use by industry, enforcement bodies and management, we used measures of carapace length (CL) throughout the study for convenience and reliability. The relationship between the two measures is linear (Jones, 1988). For the laboratory study, growth increment was defined as the difference in CL before and after one moult.

Each aquarium was supplied with aerated, filtered seawater through a continuous flow-through system and provided with sand trays (approximately 100 mm deep) to allow lobsters to maintain daily burying and foraging behaviour. Aquaria were covered with a sheet of black polypropylene to reduce light intensity to levels that were closer to those experienced by the lobsters in their natural habitat. Lobsters were fed scallop (Amusium japonicum balloti) viscera once for every 48 h at dusk. Observations on survival, moulting and tag loss were recorded every morning. A small waterproof numbered paper label, about 5 mm in diameter, was glued to the dorsal carapace of each lobster to allow individual identification and to distinguish lobsters that shed their tags from the non-tagged controls. Unconsumed food and faeces were removed with a water vacuum prior to feeding. Dead lobsters and exuviae were removed as soon as they were detected. Clean sand was supplied on three occasions.

2.2. Field tagging

Researchers on board commercial and research otter-board trawlers captured, tagged and released T. orientalis and T. indicus in Queensland coastal waters between latitudes 17°S and 24°S from May 1993 to October 1995. All trawling was undertaken at night as catch rates of the target species and lobsters are higher at night. After each trawl and within 15–20 min of being brought to the surface, all Thenus spp. were removed from the catch and placed in aerated seawater. Tag sizes and tagging methods were the same as those described for the laboratory experiment. On each night, approximately equal numbers of lobsters were tagged with small and large tags. The ointment was applied to the tag wound of half of the lobsters that were tagged with small tags, and half of those tagged with large tags. Two different release methods were also compared. On each night, approximately half of the lobsters were released on the surface by dropping them over the side of the vessel, and half were released on the bottom using an aluminium cage with a remote release-mechanism. Other possible effects, which were not controlled by design, were also examined. These were the duration (in hours) lobsters were kept on board prior to release, and the gender and size (mm CL) of lobsters at the time of tagging.

Prior to undertaking the tagging, trawler operators, fish processors and government fisheries patrol officers were supplied with recapture kits which included background information on the project, contact phone numbers of researchers, labels and plastic bags for storing recaptured lobsters and details of rewards. Ten-dollar lottery tickets, or their equivalent cash value, were offered as an incentive to fishers for providing recaptured lobsters with details of their recapture dates and locations. As a further incentive, information on time at liberty, growth and movements was provided to fishers for each recaptured lobster.

It was not possible to determine whether some recaptured lobsters had grown during their time at liberty, because of measurement error at the time of release and again at recapture. Measurement error was estimated to be 0.48 mm CL (the standard deviation of the differences between paired measurements of 200 lobsters). Recaptured lobsters were therefore considered to have grown only if the apparent growth increment was larger than the product of the measurement error (0.48 mm CL) and the value for the 95% confidence limits of a one-tailed t-distribution (1.65, n = 200) — a value of 0.8 mm CL. We therefore assumed that lobsters whose increments were larger than 0.8 mm CL were likely to have grown and only these individuals were included in analyses that examined effects on growth.

2.3. Statistical analyses

For categorical binary response variables, such as the incidence of survival, moulting, tag shedding and
recapture, generalised linear modelling (GENMOD procedure Type 3 analysis, SAS Institute Inc., 1997) was used to determine which factors and interactions were significant. The minimal adequate model was constructed by forward inclusion and backward elimination of the unbalanced interaction terms and main effects. A binomial distribution was specified in the model for these categorical response variables. The quality of fit from generalised linear models is determined from the scaled deviance statistic which has a distribution similar to the chi square (χ²) distribution. As such, the χ² significance test values are commonly reported for such tests and are used herein. Factors affecting growth increment, which is a continuous response variable with a normal distribution, were identified using a general linear model (GLM procedure, SAS Institute Inc., 1997). Models fitted were restricted to main effects and two-way interaction terms due to the limited number of replicates in the laboratory study and the limited number of recaptures from the field tagging. Recapture data were analysed separately for the two species because they have different habitats and were tagged, released and recaptured in different sectors of the fishery.

3. Results

3.1. Laboratory study

The laboratory study compared five different tagging treatments (Table 1) on incidences of survival, moulting, tag shedding and growth increments. Individual aquaria were also fitted as a treatment factor and although no significant effects were found, aquaria were retained as a blocking factor in each model.

1. Survival. Fifty-eight (73%) lobsters survived the experiment. Survival rates varied between 68.8 and 81.3% (Table 1). There was no significant difference between non-tagged controls and tagged lobsters (χ² = 1.102, d.f. = 4, P = 0.89). Neither tag size (χ² = 0.08, d.f. = 1, P = 0.78) nor application of the ointment (χ² = 0.08, d.f. = 1, P = 0.78) significantly affected survival rates.

2. Moulting. Fifty-eight (73%) lobsters moulted over the course of the experiment and one individual moulted twice. The incidence of moulting was lowest for those lobsters tagged with the large tag without ointment (50%) and highest for the non-tagged controls (100%) (Table 2). Differences between the five treatments were significant (χ² = 15.0, d.f. = 4, P = 0.005). There was a significant difference between tagged and non-tagged controls (χ² = 11.9, d.f. = 1, P < 0.001). Neither tag size (χ² = 0.28, d.f. = 1, P = 0.59) nor application of ointment (χ² = 2.59, d.f. = 1, P = 0.11) significantly affected the incidence of moulting.

3. Growth increment. Mean growth increments varied between treatments from 2.12 ± 1.32 S.D. for lobsters tagged with small tags without ointment to 2.53 ± 1.62 S.D. mm CL for the non-tagged controls (Table 2). The size of the lobsters at the beginning of the experiment had a significant effect (P < 0.01) on growth increment and was therefore included in the model as a covariate. The model parameter estimate for initial size (−0.0534) indicates that the increment decreased with increasing lobster size. There were no significant differences between the five treatments (P = 0.94). Neither tag size (P = 0.72) nor

<table>
<thead>
<tr>
<th>Tagging treatment</th>
<th>No. of lobsters subjected to treatment</th>
<th>No. of lobsters that survived</th>
<th>Mean percent survival across aquaria (±S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large tag without ointment</td>
<td>16</td>
<td>11</td>
<td>68.8 (12.5)</td>
</tr>
<tr>
<td>Small tag without ointment</td>
<td>16</td>
<td>11</td>
<td>68.8 (12.5)</td>
</tr>
<tr>
<td>Large tag with ointment</td>
<td>16</td>
<td>12</td>
<td>75.0 (20.0)</td>
</tr>
<tr>
<td>Small tag with ointment</td>
<td>16</td>
<td>11</td>
<td>68.8 (23.9)</td>
</tr>
<tr>
<td>Non-tagged control</td>
<td>16</td>
<td>13</td>
<td>81.3 (37.5)</td>
</tr>
</tbody>
</table>
Table 2

Incidence of moulting and mean growth increments for *T. orientalis* held in laboratory aquaria for approximately 4 months under different tagging treatments

<table>
<thead>
<tr>
<th>Tagging treatment</th>
<th>No. of lobsters subjected to treatment</th>
<th>No. of lobsters that moulted</th>
<th>Mean percent moulted across aquaria (±S.D.)</th>
<th>Mean growth increment across aquaria (±S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large tag without ointment</td>
<td>16</td>
<td>8</td>
<td>50.0 (20.4)</td>
<td>2.29 (1.34)</td>
</tr>
<tr>
<td>Small tag without ointment</td>
<td>16</td>
<td>10</td>
<td>62.5 (14.4)</td>
<td>2.12 (1.32)</td>
</tr>
<tr>
<td>Large tag with ointment</td>
<td>16</td>
<td>12</td>
<td>75.0 (20.4)</td>
<td>2.18 (1.45)</td>
</tr>
<tr>
<td>Small tag with ointment</td>
<td>16</td>
<td>12</td>
<td>75.0 (20.4)</td>
<td>2.33 (1.29)</td>
</tr>
<tr>
<td>Non-tagged control</td>
<td>16</td>
<td>16</td>
<td>100.0 (0.00)</td>
<td>2.53 (1.62)</td>
</tr>
</tbody>
</table>

application of the ointment (*P* = 0.63) significantly affected growth increments.

4. *Tag shedding.* Of the 64 tagged lobsters, nine lost their tags over the course of the experiment. All tag losses occurred during ecdysis and the incidence of tag loss was independent of tag size (*f^2_* = 1.25, d.f. = 1, *P* = 0.26) and application of the ointment (*f^2_* = 0.14, d.f. = 1, *P* = 0.71). The average rate of tag loss across aquaria was 0.141 ± 0.09 S.D. tags per 119 days.

3.2. Field tagging

3.2.1. *T. indicus*

Of the 2047 *T. indicus* that were tagged and released, 227 (11.1%) were recaptured. Results from the accumulated step-wise analysis of deviance (Table 3) indicated that application of the ointment to the tag wound was the most significant (*P* < 0.001) factor affecting recapture rates. Predicted recapture rates were 10.6% ± 1.0 S.E. for lobsters tagged with ointment and 0.7% ± 0.4 S.E. for those tagged without. Other influential factors were: (a) the length of time lobsters were held on board prior to release, (b) tag size and to a lesser extent, (c) release method (Table 3). The interaction between the length of time lobsters were held on board and tag size indicated that the size of the tag had little effect on recapture rates if lobsters were tagged and released within 1–2 h of being caught (Fig. 1). However, if they were held on board for extended periods (i.e. longer than 3 h) the tag size effect became significant. The overall predicted mean recapture rates were 10.9% ± 1.2 S.E. for small tags and 8.2% ± 0.9 S.E. for large tags. While these differences appear slight, they represent a (\(10.9 - 8.2\)) 33% increase in recapture rates when small tags are used rather than large tags. There was a second interaction between the length of time on board and release method (Fig. 2). Lobsters that were released with the bottom cage had a relatively constant recapture rate of about 10%, while the recapture rates for those released on the surface declined markedly with the length of time they were held on board.

A third interaction between tag size and release method was also significant (*P* = 0.01). While there were only slight tag size effects for lobsters that were released on the surface (Table 4), there was a marked difference between those released on the bottom with

Table 3

Accumulated analysis of deviance using a binomial model fit (logit link) for factors affecting recapture rates of tagged *T. indicus*

<table>
<thead>
<tr>
<th>Treatment factors</th>
<th>d.f.</th>
<th>Deviance</th>
<th>Deviance ratio</th>
<th>Chi square probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ointment</td>
<td>1</td>
<td>34.4774</td>
<td>34.48</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Time on board prior to release</td>
<td>1</td>
<td>18.8314</td>
<td>18.83</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Tag size</td>
<td>1</td>
<td>4.7315</td>
<td>4.73</td>
<td>0.030</td>
</tr>
<tr>
<td>Release method</td>
<td>1</td>
<td>0.0434</td>
<td>0.04</td>
<td>0.835</td>
</tr>
<tr>
<td>Time on board × tag size</td>
<td>1</td>
<td>21.9646</td>
<td>21.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Time on board × release method</td>
<td>1</td>
<td>18.8177</td>
<td>18.82</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Tag size × release method</td>
<td>1</td>
<td>6.6566</td>
<td>6.66</td>
<td>0.010</td>
</tr>
<tr>
<td>Residual</td>
<td>2039</td>
<td>1320.7476</td>
<td>0.64</td>
<td></td>
</tr>
</tbody>
</table>
the cage; predicted means were 13.7% ± 2.5 S.E. for small tags and 6.0% ± 1.0 S.E. for large tags. Recapture rates were not affected by the initial size of the lobsters, gender or any other factors.

Growth increments varied significantly ($P < 0.001$) with the size of the lobster at the time of release and with the period at liberty. Increments declined with increasing initial size and increased with time at liberty. When these continuous variables were included in the model as covariates, the only significant ($P < 0.05$) factor was gender. Predicted means were $8.2 ± 0.5$ S.E. mm CL for females and $6.4 ± 0.5$ S.E. mm CL for males. The model explained 68.6% of the variation in growth increments. None of the interactions were significant.

### 3.2.2. *T. orientalis*

Of the 9766 *T. orientalis* that were tagged and released, 933 (9.5%) were recaptured. Application of the ointment was the most significant factor affecting recapture rates (Table 5). There was also a significant

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**Table 4**

Predicted recapture rates (± standard error) for tagged *T. indicus* using different combinations of tag size and release method (square brackets refer to actual (observed) number recaptured/number released)

<table>
<thead>
<tr>
<th></th>
<th>Surface release</th>
<th>Bottom cage release</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small anchor tag</td>
<td>8.8 (±1.3)% [72/641]</td>
<td>13.7 (±2.5)% [57/387]</td>
</tr>
<tr>
<td>Large anchor tag</td>
<td>9.9 (±1.6)% [66/515]</td>
<td>6.0 (±1.0)% [32/504]</td>
</tr>
</tbody>
</table>
Table 5
Accumulated analysis of deviance using a binomial model fit (logit link) for factors affecting recapture rates of tagged *T. orientalis*

<table>
<thead>
<tr>
<th>Treatment factor</th>
<th>d.f.</th>
<th>Deviance</th>
<th>Deviance ratio</th>
<th>Chi square probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ointment</td>
<td>1</td>
<td>119.2065</td>
<td>119.21</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>65.7175</td>
<td>65.72</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Time on board prior to release</td>
<td>1</td>
<td>21.2717</td>
<td>21.27</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Release method</td>
<td>1</td>
<td>43.1711</td>
<td>43.17</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length at release</td>
<td>1</td>
<td>15.3546</td>
<td>15.35</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Duration of initial trawl</td>
<td>1</td>
<td>0.8836</td>
<td>0.88</td>
<td>0.347</td>
</tr>
<tr>
<td>Length at release × release method</td>
<td>1</td>
<td>6.6612</td>
<td>6.66</td>
<td>0.01</td>
</tr>
<tr>
<td>Duration initial trawl × ointment</td>
<td>1</td>
<td>6.7788</td>
<td>6.78</td>
<td>0.009</td>
</tr>
<tr>
<td>Residual</td>
<td>9757</td>
<td>5876.686</td>
<td>0.60</td>
<td></td>
</tr>
</tbody>
</table>

interaction between application of the ointment and the duration of the initial trawls used to capture the lobsters (Fig. 3). Predicted recapture rates for lobsters tagged with ointment were relatively high and remained at about 10% over the range of trawl durations. However, the predicted recapture rates for lobsters tagged without ointment declined markedly from about 6 to 1% with increasing trawl duration. These results suggest that the effects of being trawled are stressful and accumulative, and when combined with the trauma of tagging, survival and recapture rates are lowered. Application of the ointment reduces this source of mortality. Gender and time on board were also highly significant (Table 5); predicted means were 6.4% ± 0.4 S.E. for females and 12.3% ± 0.5 S.E. for males. Recapture rates (Fig. 4) declined by approximately 0.5% for every hour lobsters were held on board prior to release. There was also a second significant interaction between the length at release and release method (*P* < 0.05). Predicted recapture rates were generally higher (6–14%) for lobsters that were released with the cage and increased with increasing size of the lobsters (Fig. 5). Predicted recapture rates for lobsters that were released on the surface remained relatively constant at about 6% over a wide range of size classes (Fig. 5).

Factors affecting growth increments for *T. orientalis* were the same as those for *T. indicus*. Increments varied significantly (*P* < 0.001) with the size of the lobster at the time of release and with the period at liberty; increments declined with increasing initial size and increased with time at liberty. Gender was

![Fig. 3](image-url)  
Fig. 3. The relationship between the duration of the initial trawl used to capture lobsters and the predicted recapture rates for *T. orientalis* that were tagged with or without the application of ointment to the tag wound. Dashed lines represent 95% confidence intervals.
Fig. 4. The relationship between the length of time that lobsters were held on board prior to release and predicted recapture rates for tagged T. orientalis. Dashed lines represent 95% confidence intervals.

Fig. 5. The relationship between lobster size and predicted recapture rates for tagged T. orientalis that were released on the surface or the bottom. Dashed lines represent 95% confidence intervals.

the only other factor that significantly affected growth increments \((P < 0.001)\); predicted means were 5.93 ± 0.24 S.E. mm CL for females and 3.76 ± 0.22 S.E. mm CL for males. The model explained 46.2% of the variation in growth increments. None of the interaction terms were significant.

4. Discussion

Results from the laboratory study indicated that although survival rates and growth increments were not significantly affected by tagging, the incidence of moulting was likely to be affected. One hundred percent of the non-tagged controls moulted while the incidence of moulting in tagged lobsters ranged between 50 and 75% (Table 2). Lobsters tagged without ointment had the lowest incidences of moulting. It should be noted that the lower incidence of moulting in tagged lobsters was at least partially due to their slightly lower survival rates and not necessarily to a direct reduction in moulting. Any reduction in the incidence of moulting, however, is a concern because it suggests that growth rate estimates derived from tag-recapture studies may underestimate the true rate of growth.

The most influential factors that affected recapture rates in both species were the application of the ointment to the tag wound and the length of time lobsters spent on board prior to release (Tables 3 and 5).
Highest recapture rates were obtained when lobsters had ointment applied to the tag wound and were released within an hour after being caught, even though they were handled carefully and kept in aerated seawater while on board. Wassenberg and Hill (1993) demonstrated that *Thenus* sp. have a very high survival rate in aquaria after experiencing trawl capture. However, our results suggest that the combined effects of tagging and being held on board generate considerable stress which has a cumulative effect decreasing recapture rates the longer individuals are on board. Brown and Caputi (1983) examined factors affecting survival and recapture rates of under-sized Western Australian rock lobsters *Panulirus cygnus* that were returned to the water by fishers. They found that survival and recapture rates were lowered the longer lobsters were exposed to air, increasing temperatures and sunlight, prior to release. Penn (1975) used cage experiments to examine how the length of time on board affected the survival rates of tagged prawns (*Penaeus latiscutatus*) and non-tagged controls. He found that prawns that were held on board for 20 h prior to tagging had much higher non-tag related mortalities than those that were held on board for only 4 h.

Some of the differences between the two species may be related to their size differences. For example, gender was an important factor affecting recapture rates for *T. orientalis* but not for *T. indicus*. Recapture rates for male *T. orientalis* were about twice as high as those for females. This difference may have been related to how fishers valued the rewards for different sizes of lobsters. It is likely that the $10 reward provided a greater incentive to report recaptures of males than females because males are generally smaller and have lower market value. Large female lobsters demand $8–10 each, or more in the wholesale market and so a $10 reward for going to the trouble of storing and reporting a large female would generate little or no financial incentive. The reason why there was no gender effect for *T. indicus* may have been because it is the smaller of the two species and as a result, the reward may have been a suitable incentive for fishers to report recaptures of both sexes. Thus, the significant "gender" factor for *T. orientalis* may have actually been attributed to the size differences between the sexes. Future studies may be able negate such effects by increasing the reward for large lobsters, thus reflecting more accurately the incentives and market forces that are major influences on commercial fishers.

Another possible explanation for the lower recapture rate of female *T. orientalis* may be due to gender-related differences in catchability. However, the numbers of males and females that were caught and subsequently tagged and released were very similar, for both species, suggesting that any difference in catchability between the sexes was unlikely. A third possible explanation may be due to the regulation prohibiting possession of egg-bearing females. Recaptured tagged egg-bearing females may have been returned to the water and therefore gone unreported by fishers who were concerned about being prosecuted. However, if this were the case, then it is logical to assume a similar gender effect would have been found for *T. indicus*.

The tag size effect, which was only significant for *T. indicus*, may also be related to the size differences between species. The large tag resulted in lowered recapture rates for *T. indicus* and was particularly noticeable when lobsters were held on board for extended periods (Fig. 1) or released on the bottom with the cage (Table 4). These results suggest that *T. indicus* experiences higher stress and mortality from the large tag, possibly because it is the smaller of the two species and less tolerant of the physical trauma of tagging. Tag size had no significant main effects or interactions for *T. orientalis* during the laboratory experiment or the field studies. If the tag size effect was dependent on the size of the lobsters then it is logical to assume that there should have been a significant interaction between tag size and lobster size. However no such interaction was found for either species. Thus, it appears that the tag size effect was specific to *T. indicus*, rather than to small size classes of both species.

The shape of the tag may also affect moulting, survival and recapture rates. In the laboratory study, all tag losses occurred during ecdysis as a result of the tag getting caught on the old exuvium. It is likely similar tag losses would have also occurred in the field. Spanier and Barshaw (1993) have shown that incidences of tag-retention, survival and moulting in the Mediterranean slipper lobster, *S. latus* can be increased by placing a conical tip on the cylindrical shaft of T-bar anchor tags, which allows the shaft to pierce the old exuviae and slip through it more easily.
(see Fig. 1 in Spanier and Barshaw, 1993). In the present study, all of the tags used had cylindrical shafts with blunt ends.

The cage release method may have positive or negative effects on recapture rates, depending upon the conditions under which it is deployed. For example, for *T. indicus*, the combined effects of using the cage with lobsters tagged with small tags resulted in recapture rates that were 40% or more higher than other treatment combinations (Table 4). However, use of the cage with lobsters tagged with large tags resulted in significantly lower recapture rates. Similarly, use of the cage resulted in higher recapture rates when lobsters were held on board for extended periods, but recapture rates from the cage release were lower than surface releases when lobsters were released within 1 or 2 h of being caught (Fig. 2). For *T. orientalis*, the cage release method increased recapture rates with increasing lobster size (Fig. 5).

When the collective results for both species are considered, it appears that there may be detrimental effects from the cage on *T. indicus* and on small size classes of *T. orientalis* under some conditions, possibly as a result of increased “crowding stress”. Whenever the cage was used, in the order of 50–150 lobsters were placed inside over several minutes prior to lowering it overboard. In some instances, individuals would panic and vigorously flick their abdomens in an escape response. This behaviour would spread to other individuals in the cage and most likely contribute to further stress and trauma. The detrimental effects of the cage declined, and recapture rates increased, with increasing lobster size (Fig. 5).

The increased recapture rates associated with the cage appear to be from reduced predation during descent through the water column. The effect was particularly marked in lobsters that were on board for several hours (Fig. 2), possibly because they experienced higher stress and were less likely to be able to avoid, out-swim or hide from predators. Brown and Caputi (1983) showed that predation rates are likely to increase the longer lobsters are exposed to air, because it takes them longer to display defensive behaviour and seek shelter after release.

Robust descriptions of growth for *Thenus* spp. have yet to be published. The differences in growth increments between the sexes suggest that there are likely to be differences in growth rates between males and females. Since growth increments increased with time at liberty and declined with increasing lobster size, growth rates for *T. indicus* and *T. orientalis* are likely to conform to the general von Bertalanffy curve commonly used to describe growth in lobsters (McKoy, 1985; Annala and Bycroft, 1988).

Jones (1988) tagged and released 948 *T. orientalis* on the central Queensland coast with plastic T-bar anchor tags and reported a recapture rate of 7% (67 individuals). While recapture rates in the present study were higher than this (11.1% for *T. indicus* and 9.5% for *T. orientalis*), the results suggest further increases could be obtained in future studies of *Thenus* sp. by considering the findings above. Tag-retention and recapture rates may also be increased by using T-bar anchor tags that have conical tips on the shaft, as reported by Spanier and Barshaw (1993).

This study forms part of an initiative to quantify population parameter estimates for *Thenus* spp. on the Queensland coast and identify maximum sustainable yield. The MLS of 62 mm CW, which has recently been increased to 75 mm CW, was very small and effectively resulted in only a very small proportion of the catch being returned to the water. During the course of our work, some fisheers expressed reluctance to increase the MLS, based on the presumption that returned lobsters experience high predation rates. While our results suggest that lobsters are likely to experience some level of additional mortality after being returned to the water, it would be minimised if fisheers were regulated to return under-sized lobsters as soon as possible after they are caught.

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