

EVALUATION OF CODED MICROWIRE TAG RETENTION IN JUVENILE AMERICAN LOBSTER, *HOMARUS AMERICANUS*

Marissa D. McMahan^{1,*}, Diane F. Cowan², Graham D. Sherwood¹,
 Jonathan H. Grabowski³, and Yong Chen⁴

¹ The Gulf of Maine Research Institute, 350 Commercial St., Portland, ME 04101, USA, and School of Marine Sciences, Darling Marine Center, University of Maine, 193 Clark's Cove Rd, Walpole, ME 04573, USA

² The Lobster Conservancy, P.O. Box 235, Friendship, ME 04547, USA

³ Marine Science Center, Northeastern University, 430 Nahant Rd, Nahant, MA 01908, USA

⁴ School of Marine Sciences, University of Maine, Orono, ME 04469, USA

ABSTRACT

The reliability of population dynamics and stock assessment models hinges on accurate life-history information. Mark-recapture studies represent a commonly used technique to investigate crustacean growth, mortality, and migrations. We evaluated tagging by coded microwire tags for the American lobster, *Homarus americanus* H. Milne Edwards, 1837, in a controlled study to determine tag retention and any influence on growth increment, intermolt duration, or survival. Microwire tags were injected into the propodus of the second right walking leg and two size classes (12-19.6 and 19.7-30 mm carapace length [CL]) were tested by two individual taggers. Overall tag retention was 96%. Tag retention after first ecdysis was 95% for the 12-19.6 mm CL and 92.5% for the 19.7-30 mm CL size class. There was no significant difference in tag retention between taggers, growth between tagged and untagged lobsters, or intermolt duration between tagged and untagged lobsters ($P > 0.05$ for all tests). Tag-induced mortality did not occur. These results support the further use of coded microwire tags to explore life-history variables for juvenile lobsters in the wild.

KEY WORDS: American lobster, coded microwire tags, fisheries management, *Homarus americanus*, mark-recapture, Nephropidae, tag loss and retention

DOI: 10.1163/193724012X626494

INTRODUCTION

Characterization of population dynamics, including growth, movement, and mortality, is necessary for accurate stock assessment and management of a species. Mark-recapture studies (i.e., tagging) represent one of the most commonly used techniques for investigating population dynamics in aquatic animals, e.g., fish. However, using this technique with crustaceans can be problematic because externally placed tags, e.g., sphyron or streamer tags, may be lost during ecdysis (Ennis, 1986; Comeau and Savoie, 2001; Rowe and Haedrich, 2001; O'Malley, 2008). Tracking juvenile American lobsters, *Homarus americanus* H. Milne Edwards, 1837, through successive molts requires a tag that will endure ecdysis and is small enough to minimize the risk of tag-induced mortality, tag loss, and entanglement. The use of coded microwire tags (Northwest Marine Technology, Washington, USA [NMT]), first used in juvenile fish (Jefferts et al., 1963), and successfully applied to lobsters (Ennis, 1972), appears to be a solution. The tags are biologically inert, and should be retained through several molt cycles because of their complete internal placement. Bannister et al. (1994) reported recapturing coded microwire tagged juvenile lobsters, *Homarus gammarus* (Linnaeus, 1758), in

adults up to 8 years after release as hatchery-reared juveniles.

Coded microwire tags have been used to mark juvenile lobsters by insertion into the abdominal muscle tissue and into the body cavity at the base of the pereopod (Wickins et al., 1986; Uglem and Grimsen, 1995; James-Pirri and Cobb, 1999; Sharp et al., 2000). The advantage of these methods is that it allows tagging of smaller individuals; the disadvantage is that it precludes multiple recaptures because it is necessary to sacrifice individuals to recover tags. Krouse and Nutting (1990) evaluated inserting coded microwire tags into the muscle tissue of the second right pereopod of juvenile lobsters, *H. americanus*. This method provided a way to extract the tags easily (by clipping the tip of the pereopod) and implant a new tag in another pereopod for subsequent recaptures from which developed the mark-recapture time series for wild-captured juvenile lobsters that is the impetus for this study (Cowan, 1999; Cowan et al., 2001).

The purpose of this study was to evaluate the use of coded microwire tags inserted into the muscle tissue of the propodus of juvenile lobster pereopods on tag retention through ecdysis. We hypothesized that tag retention rates would be high, unrelated to the size of the lobster, and independent of tagger identity. We also hypothesized that

* Corresponding author; e-mail: marissa.mcmahan@maine.edu

tagging would not influence growth, survival, or intermolt duration.

MATERIALS AND METHODS

Experimental Design

To evaluate tag retention and the influence of tagging on growth and survival of juvenile lobsters we partitioned lobsters ranging from 12–30 mm CL into two size classes: 12–19.6 mm CL and 19.7–30 mm CL. Each size class included 60 individuals: 20 controls, 20 tagged by tagger 1, and 20 tagged by tagger 2. Only intermolt stage lobsters with two claws and no more than one missing leg were used.

Field Collection and Study Site

The lobsters used in this study were collected by hand at the mouth of the Sheepscot River (43°48'35.00"N, 69°42'56.00"W), in Georgetown, Maine starting in June 2009. Due to availability, collection of lobsters smaller than 19.7 mm CL began in July 2009. After capture, each lobster was carefully wrapped in a paper towel soaked with sea water, and then placed in a cooler to prevent injury and thermal stress. For our experiment, lobsters in the smaller size class were housed in 300 ml 6.5 × 9 cm individual plastic containers with screw top lids and 4 mm holes drilled in them. These containers were placed inside 0.5 × 0.8 × 0.4 m plastic hinged-lid lobster crates (IPL Products, Ltd, Quebec, Canada). Lobsters in the larger size class were kept in 2.54 × 1.27 cm rubber coated mesh wire cages divided into 14 cm³ individual cells that were also stored inside 0.5 × 0.8 × 0.4 m plastic hinged-lid lobster crates tied to a wooden float. The wooden float was located in a cove at the mouth of the Sheepscot River (Georgetown, ME; 43°48'47.55"N, 69°43'6.16"W) roughly 200 meters from the collection site. We performed the study at this location because it was proximal to the collection site, and the harbor was sheltered. By conducting the experiment in the field, the tagged lobsters were exposed to abiotic conditions similar to those of lobsters tagged in the wild.

Tagging Procedure and Experiment

Initial tagging of the 19.7–30 mm CL size class was conducted on 2 June 2009. During tagging each lobster was individually removed from its container and measured to the nearest tenth of a millimeter (estimated error measurement = ±0.2). Binary coded microwire tags measuring 0.25 mm in diameter by 1.0 mm in length were implanted into the second right walking leg in the soft tissue of the joint between the dactylus and propodus using a single shot injector (Northwest Marine Technology, Washington, USA [NMT]). Taggers were positioned sitting on the float, and lobsters were held against the knee of the tagger while the second right periopod was held between thumb and forefinger to open the dactyl while the tag was inserted through the soft tissue of the joint to placement in the medial muscle tissue of the propodus.

Lobsters were passed over a horse shoe magnet to magnetize the tag, and then passed over a V-Detector (NMT) several times to ensure that the tag was in place. The inner right uropod was then given a v-notch clip, identical to the method applied in the field in order to determine which leg

the tag is in when a lobster is recaptured, and the lobsters were returned to their cells. Each control lobster was left in its cell while the other lobsters were removed by the recorder and given to their tagger. Both test and control specimens were held within their cells for the remainder of the experiment. Tagging of the 12–19.6 mm CL size class took place on 6 August 2009. These animals were not v-notched because such cutting would result in the removal of a large portion of uropod in small lobsters.

Lobsters were fed the day after being tagged, and then twice a week after the initial feeding. Each lobster was fed the same species and approximately the same amount (10–15 g) at each feeding event. The diet varied from week to week and consisted of mussels, worms, clams, periwinkles, shrimp, crabs, and fish. Food was removed from the cages within 24 hours to prevent contamination but caste shells (exuviae) were left in the containers for lobsters to consume. Lobsters were also exposed to plankton, amphipods, and juvenile fish in the water column, and may have consumed them. Mortality, limb loss, molt stage, and salinity were monitored at least every other day, and in most instances daily. Water temperature was recorded hourly using an Onset[®] temperature data logger deployed in one of the housing crates and ranged from 5.7 to 22.7°C (mean 13.2°C). Salinity was measured daily with a refractometer and ranged from 24 to 35 psu (mean 31 psu).

Four to five days after molting (once the newly formed exoskeleton had hardened enough for handling) lobsters were passed over the detector to determine if the tag had been retained. To test for mortality associated with periopod removal (to extract existing tag) and retagging, the larger size-class of lobsters was monitored through a second molt cycle. As is done for the field studies, we cut off the end of the second right periopod at the distal-most joint to remove the first tag before inserting a second tag in the third right walking leg, and making a second clip in the outer right uropod. The section of periopod removed from the lobster was passed over the detector to ensure that the tag had been removed. The retagging process mirrored how recaptured lobsters are handled in the field, and was included in the study because it is a more invasive and potentially damaging process that could change limb loss, mortality, and tag-retention rates. For the 19.7–30 mm CL lobster size class, 32 of some 40 tagged lobsters had undergone ecdysis and were hard enough to be retagged by 6 July 2009. The remaining eight lobsters were retagged on 6 August 2009. After monitoring the 19.7–30 mm CL size class through a second molt cycle, each lobster was measured and released. The last lobster was released on 1 November 2009.

Analytical Methods

Analysis of variance was used to determine if retention was influenced by size class or tagger, and if residual percent growth significantly differed between lobsters tagged by tagger 1, tagger 2, and controls. Residual percent growth was determined using linear regression, which allowed us to focus on the effects of tagger while controlling for any size effects that potentially influence growth. Analysis of variance was used to test if intermolt interval between first and second ecdysis of the 19.7–30 mm CL size class significantly differed between control lobsters, those tagged by tagger 1,

and those tagged by tagger 2. The above statistical analyses were conducted using SPSS 16.0 statistical software. The influence of the tagging method on mortality was not tested because the single mortality observed occurred within the control group.

RESULTS

Overall retention of the 120 tags implanted into juvenile lobsters was 96% (Table 1). Of the five tags lost, one was due to autotomy of the tagged leg (second right periopod). The cause of tag loss in the other four lobsters is not known. Among lobsters tagged in the 19.7-30 mm CL size range, 38 (95%) retained the initial tag after the first molt and 39 (97.5%) retained the second tag through the second molt. Within the 12-19.6 mm CL size range, 38 (95%) retained the tag through one molt cycle. The smaller lobsters were not followed through a second molt. Lobster tag retention did not differ between taggers or size classes (ANOVA, $P > 0.05$ for all effects, Table 1).

Linear regression of percent growth as a function of initial CL indicated that lobster growth decreased as lobsters increased in size (Fig. 1). Residual growth was calculated from the regression equation and used to test tagger effects on growth within small and large juvenile lobsters (Fig. 2). Residual percent growth did not significantly differ among control lobsters (untagged), those tagged by tagger 1, and those tagged by tagger 2 after the first molt for small and large lobsters and the second molt for large lobsters (ANOVA, $P > 0.05$ for all tests). Intermolt duration between first and second molt of the 19.7-30 mm CL size class ranged from 32 to 97 days and did not significantly differ among control lobsters, those tagged by tagger 1, and those tagged by tagger 2 (ANOVA, $P > 0.05$, Fig. 3).

Of the lobsters tagged twice, and subsequently having the tip of the periopod containing the initial tag clipped, 25% autotomized the clipped leg within three days. This did not influence retention because the autotomized leg no longer contained a tag. The single case of mortality recorded during the study was a control lobster that was within the 12-19.6 mm CL size range.

DISCUSSION

Our results show that repeated tagging of juvenile lobsters, *H. americanus*, using individually coded microwire tags did not significantly influence retention of tags between size classes or taggers. Overall retention of tags by juvenile lobsters through ecdysis was high (96%) compared to a previous study evaluating this method, in which retention varied between 52-86% (Krouse and Nutting, 1990). The

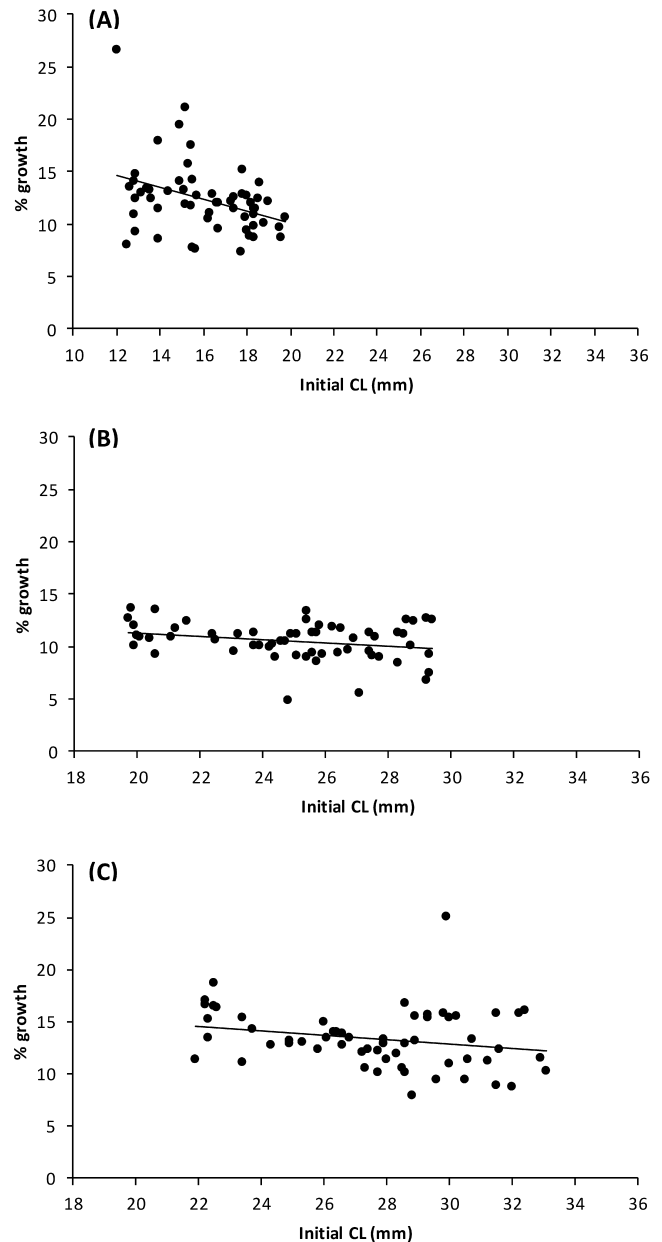


Fig. 1. Percent growth of juvenile *Homarus americanus* as a function of initial carapace length (CL). A, 12-19.6 mm CL; B, 19.7-30 mm CL first molt; C, 19.7-30 mm CL second molt size classes. Linear regression for 12-19.6 mm CL size class: % growth = $21.2 - 0.55 \times$ initial CL ($r^2 = 0.13$, $P < 0.05$, $n = 59$); linear regression for 19.7-30 mm CL size class first molt: % growth = $14.5 - 0.16 \times$ initial CL ($r^2 = 0.07$, $P = 0.05$, $n = 59$); linear regression for 19.7-30 mm CL size class second molt: % growth = $21.6 - 0.30 \times$ initial CL ($r^2 = 0.09$, $P < 0.05$, $n = 60$).

Table 1. Retention of coded microwire tags by juvenile *Homarus americanus* among size class and tagger. The 19.7-30 mm carapace length (CL) size class includes first and second molt.

Size class	Tagger 1		Tagger 2	
	Tagged	Retained tag	Tagged	Retained tag
12-19.6 mm CL	20	20 (100%)	20	18 (90%)
19.7-30 mm CL (1 st molt)	20	19 (95%)	20	19 (95%)
19.7-30 mm CL (2 nd molt)	20	20 (100%)	20	19 (95%)

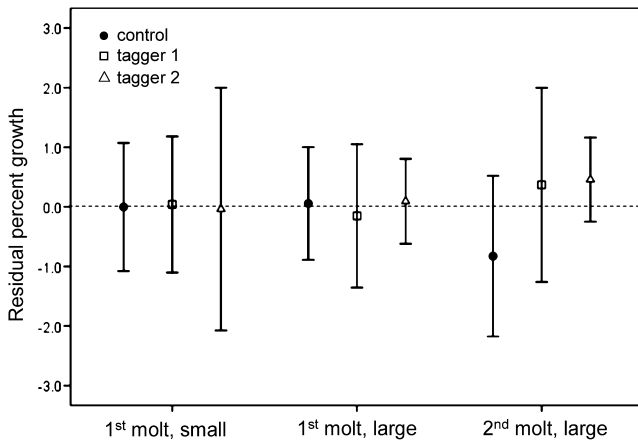


Fig. 2. Residual percent growth of juvenile *Homarus americanus* in control, tagger 1, and tagger 2 groups for first molt in small (12-19.6 mm carapace length [CL]) and first and second molt in large (19.7-30 mm CL) size classes (ANOVA, $P > 0.05$). Error bars represent 95% confidence intervals.

rate of retention found by Krouse and Nutting (1990) was thought to be low due to the difficulty of placing the tag in the cuticle of premolt lobsters. We tagged lobsters in the integument between the dactyl and propodus of the periopod to avoid the cuticle. Also in contrast to the previous study, we conducted this study in the field to avoid possible lab-induced effects. Of the five tags not retained in this study, only one was due to autotomy of the tagged leg. The other four may have been due to inadequate placement; however this amount of tag loss (3%) was not significant. Furthermore, the rates of retention between individual taggers did not significantly differ, and tagging had no effect on growth or survival. Thus, the tagging method used in this study seems relatively robust against hidden treatment effects that may bias interpretation of tagging datasets from field studies and their use in resource management.

Studies evaluating coded microwire tag retention of post-larval and juvenile *H. americanus* (James-Pirri and Cobb, 1999), *H. gammarus* (Wickins et al., 1986; Uglem and Grimsen, 1995; Linnane and Mercer, 1998), *Panulirus argus* Latereille, 1804 (Sharp et al., 2000), and *Procambarus clarkii*

(Girard, 1852) (cf. Isely and Eversole, 1998) tagged in the pleon or base of the fifth periopod have also found high retention ranging from 85 to 100% and little to no influence on survival and growth. While tag placement in the pleon or base of the periopod may be easier, allows for tagging smaller individuals, and certainly results in sufficient tag retention, the problem of having to sacrifice the animal to recover the tag upon recapture makes it impossible to track growth or movement over multiple captures.

Our method using coded microwire tags may be preferable to other tagging options. Visible implant elastomer (VIE) tags (Northwest Marine Technology, Washington, USA [NMT]) have been successfully applied to juvenile *H. gammarus* (Uglem et al., 1996; Linnane and Mercer, 1998), *Jasus edwardsii* (Hutton, 1875) (cf. Woods and James, 2003), *Orconectes obscurus* (Hagen, 1870) (cf. Clark and Kershner, 2006), *P. clarkii* (Isely and Stockett, 2001), and *Cherax destructor* Clark, 1936 (Jerry et al., 2001) and do not require sacrificing the individual to retain the tag. However, this method has limited coding capacity (tags are identified by color rather than number) and is more suitable for marking groups as opposed to individuals. Evaluation of passive integrated transponder (PIT) tags used on larger juvenile and adult lobsters as well as crayfish have also shown high rates of retention and survival (Robinson et al., 2000; Bubb et al., 2002, 2006; O'Malley, 2008; Frusher et al., 2009); and do not require sacrificing recaptured individuals. Yet this method cannot be applied to small juvenile lobsters due to the size of the tag (12-20 mm). Furthermore, PIT tags are considerably more expensive than most conventional tags. Finally, both VIE and PIT tags are commonly (and most successfully) applied to the abdomen, which causes concern that they may be ingested if tagged individuals end up in the commercial market.

Developing a non-invasive method that can be used to measure growth of individual lobsters across multiple time intervals is critical for examining variability in growth curves. Advantages of using coded microwire tags injected into the propodus of juvenile lobsters include high tag retention, no apparent effect on growth or survival, relatively low cost, and low chance of ingestion. Disadvantages include having to clip the leg tip to recover the tag, having to re-

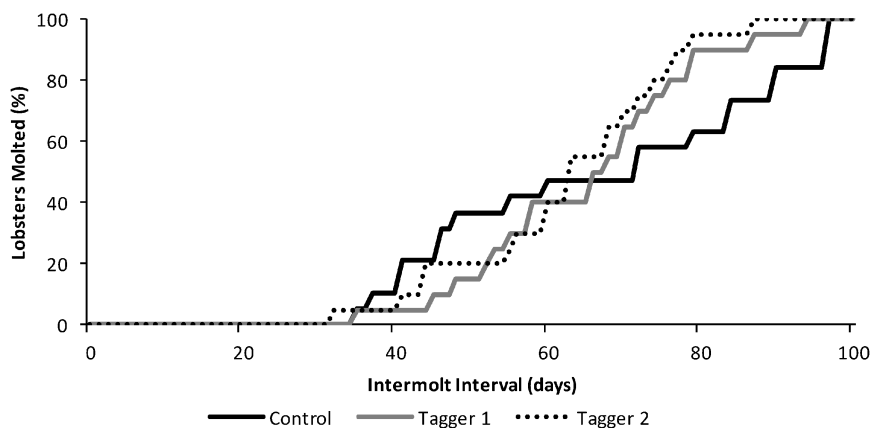


Fig. 3. Percent of juvenile *Homarus americanus* molted in relation to days between first and second molt for control, tagger 1, and tagger 2 groups in the 19.7-30 mm carapace length (CL) size class (ANOVA, $P > 0.05$).

tag the individual once it is recaptured, and the subsequent labor intensive steps required to read and match tags to large numbers of individuals.

To determine whether measurement of multiple growth increments for each lobster results in additional biases/tagging induced mortality, our study included monitoring the 19.7-30 mm CL size class after the first tag was removed and a second tag injected in the third right walking leg. Multiple tagging subjects the lobster to possible leg loss and could result in elevated infection/predation rates. Our results showed that clipping the leg tip prior to subsequent tagging did not influence growth or survival. However, 25% of the lobsters autotomized the clipped leg, which could result in reduced growth in length due to regeneration (Juanes and Smith, 1995).

It is also important to point out that our growth and survival results may not reflect what happens in nature since our tagged lobsters were maintained in predator-free cages. Once the leg is clipped, bleeding could alert predators to the presence of the injured lobster, thereby increasing risk of predation. Similarly, clipping the uropod (in the 19.7-30 mm CL size class) to indicate the presence of a tag, did not significantly influence any of the parameters tested, but survival results may be different for lobsters released into the wild if it attracts predators. Furthermore, tag retention may be lower in the wild if lobsters release the tagged leg in the presence of a predator. Lobsters might also be more apt to lose the tagged leg if the tag impairs function in a more heterogeneous environment than our tag containers. Further experimentation on the effects of predators and habitat heterogeneity on tag retention and tagging induced artifacts on lobster growth and mortality is merited.

Another potential limitation of this method is that it is more labor intensive than typical mark-recapture studies because the clipped leg must be brought back to the lab and dissected in order to read the tag. This considerably increases the amount of time it takes to obtain information about recaptured individuals. However, this added time cost is more than compensated for by the added value if researchers are interested in obtaining multiple recapture measurements throughout several molts without sacrificing the animal. Thus far, recapture rates from previous tagging efforts (Cowan, 1999; Cowan et al., 2001) have been encouraging.

Overall our results indicate that tagging using coded micro-wire tags inserted into the periopod, subsequent removal, and retagging is a suitable method for tagging small juvenile American lobsters, *H. americanus*. Using this method for mark-recapture studies should provide growth and survival data that is not influenced by the tagging process, and also offers a way of monitoring juveniles through multiple molt cycles. Thus, long-term datasets collected using this method should be of great value to lobster population assessments and resource managers.

ACKNOWLEDGEMENTS

We thank Jim McMahan who helped collect and monitor the juvenile lobsters over the duration of the study, John and Deb Darling whose float we used as a make-shift laboratory and housing area for the lobsters, and the National Science Foundation to GDS, JHG and YC (CNH-0709527) for providing funding.

REFERENCES

- Bannister, R. C. A., J. T. Addison, and S. R. J. Lovewell. 1994. Growth, movement, recapture rate and survival of hatchery-reared lobsters (*Homarus gammarus* (Linnaeus, 1758)) released into the wild on the English east coast. *Crustaceana* 67(2): 156-172.
- Bubb, D. H., T. J. Thom, and M. C. Lucas. 2006. Movement patterns of the invasive signal crayfish determined by PIT telemetry. *Canadian Journal of Zoology* 84: 1202-1209.
- , M. C. Lucas, T. J. Thom, and P. Rycroft. 2002. The potential use of PIT telemetry for identifying and tracking crayfish in their natural environment. *Hydrobiologia* 483: 225-230.
- Clark, E. M. 1936. The freshwater and land crayfishes of Australia. *Memoirs of Museum Victoria* 10: 5-58.
- Clark, J. M., and M. W. Kershner. 2006. Size-dependent effects of visible implant elastomer marking on crayfish (*Orconectes obscurus*) growth, mortality, and tag retention. *Crustaceana* 79: 275-284.
- Comeau, M., and F. Savoie. 2001. Growth increment and molt frequency of the American lobster (*Homarus americanus*) in the southwestern Gulf of St. Lawrence. *Journal of Crustacean Biology* 21: 923-936.
- Cowan, D. F. 1999. Method for assessing relative abundance, size distribution, and growth of recently settled and early juvenile lobsters (*Homarus americanus*) in the lower intertidal zone. *Journal of Crustacean Biology* 19: 738-751.
- , A. R. Solow, and A. Beet. 2001. Patterns in abundance and growth of juvenile lobster, *Homarus americanus*. *Marine and Freshwater Research* 52: 1095-1102.
- Ennis, G. P. 1972. Growth per molt of tagged lobsters (*Homarus americanus*) in Bonavista Bay, Newfoundland. *Journal of the Fisheries Research Board of Canada* 29: 143-148.
- . 1986. Sphyrion tag loss from the American lobster *Homarus americanus*. *Transactions of the American Fisheries Society* 115: 914-917.
- Frusher, S. D., D. Hall, P. Burch, and C. Gardner. 2009. Combining passive integrated transponder tags with conventional T-bar tags to improve tag reporting rates in a rock lobster trap fishery. *New Zealand Journal of Marine and Freshwater Research* 43: 347-353.
- Girard, C. 1852. A revision of the North American Astici, with observations on their habits and geographical distribution. *Proceedings of the Academy of Natural Sciences of Philadelphia* 6: 87-91.
- Hagen, H. A. 1870. Monograph of the North American Astacidae. *Memoirs of the Museum of Comparative Zoology at Harvard College* 2(1): i-viii, 1-109, xi pl.
- Hutton, F. W. 1875. Descriptions of two new species of Crustacea from New Zealand. *Transactions of the New Zealand Institute* 7: 279-280.
- Isely, J. J., and A. G. Eversole. 1998. Tag retention, growth, and survival of Red Swamp Crayfish *Procambarus clarkia* marked with coded wire tags. *Transactions of the American Fisheries Society* 127: 658-660.
- , and P. E. Stockett. 2001. Tag retention, growth, and survival of Red Swamp Crayfish marked with a visible implant tag. *North American Journal of Fisheries Management* 21: 422-424.
- James-Pirri, M. J., and J. S. Cobb. 1999. Influence of coded micro-wire tags on postlarval lobster (*Homarus americanus*) behavior. *Marine and Freshwater Behaviour and Physiology* 32: 255-259.
- Jefferts, K. B., P. K. Bergmen, and H. F. Fiscus. 1963. A coded wire identification system for macro-organisms. *Nature (London)* 198: 460-462.
- Jerry, D. R., T. Stewart, I. W. Purvis, and L. R. Piper. 2001. Evaluation of visual implant elastomer and alphanumeric internal tags as a method to identify juveniles of the freshwater crayfish, *Cherax destructor*. *Aquaculture* 193: 149-154.
- Juanes, F., and L. D. Smith. 1995. The ecological consequences of limb damage and loss in decapod crustaceans: a review and prospectus. *Journal of Experimental Marine Biology and Ecology* 193: 197-223.
- Krouse, J. S., and G. E. Nutting. 1990. Evaluation of coded micro-wire tags inserted in legs of small juvenile American lobsters. *American Fisheries Society Symposium* 7: 304-310.
- Latreille, P. A. 1804. *Histoire naturelle... des Crustacés et des Insectes. Histoire naturelle, générale et particulière, des Crustacés et des Insectes. Ouvrage faisant suite aux oeuvres de Leclerc de Buffon, et partie du cours complet d'histoire naturelle rédigé par C.S. Sonnini, membre de plusieurs sociétés savantes. G. L. L. Buffon (ed.). Vol. 7. F. Dufart, Paris.*

- Linnaeus, C. 1758. *Systema Naturae per Regna Tria Naturae, Secundum Classes, Ordines, Genera, Species, cum Characteribus, Differentiis, Synonymis, Locis* (edit. 10). Vol. 1. Laurentii Salvii, Holmiae [Stockholm].
- Linnane, A., and J. P. Mercer. 1998. A comparison of methods for tagging juvenile lobsters (*Homarus gammarus* L.) reared for stock enhancement. *Aquaculture* 163: 195-202.
- Milne Edwards, H. 1834-1837. *Histoire naturelle des Crustacés comprenant l'anatomie, la physiologie et la classification de ces animaux*. Librairie Encyclopédique de Roret, Paris.
- O'Malley, J. M. 2008. Evaluations of tag retention and a device for releasing discarded Hawaiian spiny lobsters *Panulirus marginatus*. *North American Journal of Fisheries Management* 28: 619-624.
- Robinson, C. A., T. J. Thom, and M. C. Lucas. 2000. Ranging behaviour of a large freshwater invertebrate, the white-clawed crayfish *Austropotamobius pallipes*. *Freshwater Biology* 44: 509-521.
- Rowe, S., and R. L. Haedrich. 2001. Streamer tag loss from American lobsters. *Transactions of the American Fisheries Society* 130: 516-518.
- Sharp, W. C., W. A. Lellis, M. J. Butler, W. F. Herrnkind, J. H. Hunt, M. Pardee-Woodring, and T. R. Matthews. 2000. The use of coded microwire tags in mark-recapture studies of juvenile Caribbean spiny lobster, *Panulirus argus*. *Journal of Crustacean Biology* 20: 510-521.
- Uglen, I., and S. Grimssen. 1995. Tag retention and survival of juvenile lobsters, *Homarus gammarus* (L.), marked with coded wire tags. *Aquaculture Research* 26: 837-841.
- , H. Nøess, E. Farestveit, and K. E. Jørstad. 1996. Tagging of juvenile lobsters (*Homarus gammarus* (L.)) with Visible Implant Fluorescent Elastomer tags. *Aquacultural Engineering* 15: 499-501.
- Wickins, J. F., T. W. Beard, and E. Jones. 1986. Microtagging cultured lobsters, *Homarus gammarus* (L.), for stock enhancement trials. *Aquaculture and Fisheries Management* 17: 259-265.
- Woods, C. M. C., and P. J. James. 2003. Evaluation of visible implant fluorescent elastomer (VIE) as a tagging technique for spiny lobsters (*Jasus edwardsii*). *Marine and Freshwater Research* 54: 853-858.

RECEIVED: 12 May 2011.

ACCEPTED: 2 November 2011.