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Use of formulated diets as replacements for *Artemia* in the rearing of juvenile American lobsters (*Homarus americanus*)

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Abstract

American lobsters, *Homarus americanus*, have been successfully reared in hatchery operations for over a century, yet formulated diets have never been commercially produced. In recent years, commercial *Artemia* replacement (CAR) diets have been developed and marketed for use in aquaculture production of marine shrimp. Three separate experiments assessed the utility of rearing American lobsters on these shrimp CAR diets. First, survival and growth of stage IV American lobsters fed one of three CAR diets (Artemac 5, CAR1; Economac 4, CAR2; and Progression 3, CAR3) were compared to those of animals fed frozen adult n-3 fatty acid enriched *Artemia*. Survival to 3 months was highest for animals fed CAR3 (85%), while animals fed *Artemia* had the greatest weight gain (>6 % day^{-1}). A cost/benefit ratio analysis showed that CAR2 was the most cost efficient for juvenile production because of its low overall purchase cost. Second, stage IV lobsters were fed either CAR2 or frozen adult n-3 fatty acid enriched *Artemia* exclusively, or in combination (2:5, and 5:2). Again, CAR2 was a cost effective feed to use, even as a partial replacement for *Artemia*. Survival was higher in diets that included CAR2, and feeding it two days per week compensated for low quality *Artemia*. Finally, 1.5 year old lobsters fed a gelatin-bound mix of 80% CAR2 and 20% frozen *Artemia* for five months survived and grew equally well compared to lobsters fed gelatin-bound frozen adult *Artemia*, and better than a custom formulated maintenance diet. The benefits of incorporating formulated feeds into American lobster rearing programs to increase the effectiveness of enhancement programs is discussed.

Keywords: *Artemia*; Artificial feed; Captive rearing; Cost/benefit ratio; *Homarus americanus*; Stock enhancement

1. Introduction

Formulated, commercially available feeds are preferred for use in aquaculture operations due to their lower cost, ease of storage, and reduced incidence of bacterial contamination compared to live or frozen foods (Cox and Johnston, 2003; Fiore and Tlusty, 2005). For early juvenile American lobsters (*Homarus*

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americanus), live adult *Artemia* is considered to provide optimal nutrition (Conklin, 1995), although the cost of its purchase or production is prohibitive for large-scale hatchery use. The traditional alternative has been to feed frozen adult *Artemia,* which supports growth rates approximately 60% of that of live *Artemia* (Conklin, 1995). Research on early benthic juveniles in the 1970s and 1980s determined that protein and lipids were the most critical components for maximal survival and growth. Minimum dietary protein level for rapid growth was determined to be approximately 40%, optimal crude lipid was 14–15%, and cholesterol and phospholipids were found to be essential in preventing molt death syndrome (Conklin, 1995; D'Abramo et al., 1981). Excellent formulated diets (high survival and growth rates 60% to 80% that of the live *Artemia* standard) were developed in the lab (Conklin et al., 1980; D'Abramo and Conklin, 1985; Bordner et al., 1986). Unfortunately American lobster aquaculture efforts were largely abandoned by the early 1990s due to technological gaps in rearing management (Aiken and Waddy, 1995) coupled with a strong resurgence in fishery landings (National Marine Fisheries Service, 2002). Consequently, the absence of an industry precluded formulated juvenile lobster diets from becoming commercially available (Aiken and Waddy, 1995).

Interest in the aquaculture production of American lobsters is now growing because of concerns of overfishing, health issues, and a rapid decline in lobster stocks south of Cape Cod, Massachusetts, particularly in the Long Island Sound fishery (Atlantic States Marine Fisheries Commission, 2004). In addition, European lobster (*Homarus gammarus*) stocks have been successfully enhanced. When stocks in Norway declined to 30% of historic levels, a concerted effort was directed to augment the fishery. The Norwegian program reared juveniles for 5 to 19.5 months (to 11.8–21.1 mm carapace length) in the hatchery before release, and was ultimately successful with 50% of fishery landings being of hatchery origin (Agnalt et al., 1999). Similarly, in the United Kingdom, wild stocks were increased through the release of 15 mm CL (stage X to XII) lobsters (Addison and Bannister, 1994). These scenarios therefore offer promise that an American lobster enhancement program could succeed through the adoption of European methodology.

At present, the augmentation of American lobster stocks needs to be re-evaluated based on (1) severe and widespread stock declines, and (2) the potential feasibility of homarid lobster enhancement based on the European model. In addition to a probable need and the potential for success, the past two decades have brought rapid increases in global aquaculture production. This success stems from improvements in the very areas in which American lobster aquaculture was lacking including hatchery technology, broodstock management, and in particular, developments in feed production (Aiken and Waddy, 1995). Of these, the advancement of the feed industry has been most significant, particularly in the crustacean sector. Artificial diets are now utilized in the production of all life history stages of marine shrimp, including commercial *Artemia* replacement (CAR) diets manufactured for postlarval penaeid shrimp. In both penaeid shrimp and clawed lobster postlarval stages, *Artemia* has been shown to provide excellent nutrition (Wickins and Lee, 2002; Conklin, 1995). As CAR diets developed for shrimp have been formulated to match *Artemia* nutritionally, they may also be an effective and economical off-the-shelf feed for the hatchery production of early benthic phase juvenile lobsters.

Previous work has shown that some CAR diets can be used as partial replacements for live or frozen *Artemia* in the rearing of pelagic lobster larvae (Fiore and Tlusty, 2005). Here, three experiments were conducted to determine whether these CAR diets are a viable alternative to frozen *Artemia* as a hatchery diet for juvenile American lobsters. Temperature and feeding schedules in our facility had been optimized for production and long-term maintenance of juveniles rather than for promoting maximum growth rates. Therefore, these experiments were designed to evaluate performance on formulated diets relative to the frozen *Artemia* standard. The First experiment examined weight gain, condition, and survival of early juvenile lobsters beginning at stage IV fed one of three different CAR diets, or a frozen n-3 fatty acid enriched adult *Artemia* diet. The Second experiment examined the performance of early juveniles beginning at stage IV fed combinations of the best performing CAR diet and frozen n-3 fatty acid enriched adult *Artemia*. To determine the most cost effective diets within these two experiments, the survival and biomass benefits were compared with