NOAA
National Marine
Fisheries Service

Fishery Bulletin
established 1881

Spencer F. Baird
First U.S. Commissioner
of Fisheries and founder
of *Fishery Bulletin*

Economic valuation of stock enhancement of banana prawn (*Fenneropenaeus merguiensis*) in the Strait of Hormuz

Nassir Niamaimandi (contact author)[1]
Gholam-Abbas Zarshenas[2]

Email address for contact author: nniamaimandi@yahoo.com

[1] Iran Shrimp Research Institute
P.O. Box 1374
Bushehr, Iran

[2] Iranian Fisheries Research Organization
Karaj-Pykanshahr
Sarvenaz St.
P.O. Box 14155-6116
Tehran, Iran

Abstract—Economic return was estimated for the stock enhancement of banana prawns (*Fenneropenaeus merguiensis*) released in waters of the Strait of Hormuz along the coast of Hormozgan Province in Iran. Of the 4.7 million juvenile banana prawns that were cultured and released during the period of June–July 2010, 50,000 were marked by injection with red fluorescent elastomer. During the fishing season in November 2010, 11 marked prawns were recovered (a recovery rate of 0.022%).The mean weight of marked prawns at release and recovery was 1.08 g (± standard deviation [SD] 0.1) and 22.06 g (SD 4.9), respectively, representing a growth rate that ranged from 0.88 to 1.41 g weeks^{-1}. On the basis of the number of prawns released and the recovery rate, the shrimp catch in Hormozgan in 2010 was estimated to be about 1034 released prawns with a mean weight of about 22.80 kg. The production cost for 4.7 million prawns was USD 18,800, and the local market value of landed prawns was USD 3.440 kg^{-1}. Therefore, the total value of the estimated 1034 landed prawns was USD 77.50, indicating a profit to production ratio of 0.0041. These results, particularly the percentage of recaptured prawns, shows that this type of release operation is not economically feasible.

Manuscript submitted 22 June 2013.
Manuscript accepted 12 November 2014.
Fish. Bull. 113:40–46 (2015).
doi: 10.7755/FB.113.1.4

The development of the penaeid prawn trawl fishery along the Iranian coast of the Persian Gulf began in 1959 (Van Zalinge, 1984). Shrimp fishing activities by large-scale industrial fleets expanded rapidly, and technology later adapted to artisanal fisheries. Shrimp fishing effort along other Gulf countries soon followed: Saudi Arabia in 1963, Bahrain in 1966, Kuwait in 1967, and Qatar in 1969. Maximum shrimp landings reached 9600 metric tons (t) in Iran for the period of 1964–1965 and 3335 t for Kuwait in 1966–1967, and industrial landings reported by Saudi Arabia and Bahrain peaked at 7400 t in 1973–1974 (Van Zalinge, 1984).

The period of 1959–1969 was a boom phase for the industrial shrimp fisheries that was characterized by high catch rates, increased landings, and the establishment of new companies. In the late 1970s, shrimp catches in the Persian Gulf declined dramatically, and, as a result of that decrease, several fishing companies ceased activities in 1979 (FAO[1]). Increased fishing effort, lower catch rates, and competition with passive types of fishing techniques gradually led to regulatory management measures. These included a reduction in fishing effort, temporal and spatial closures, and, in some cases, total closures of shrimp fisheries. Today, the shrimp fishery in Iranian waters of the Persian Gulf has input and output controls of limited entry, closed seasons, and closed areas. The opening and closure of the fishery (i.e., duration of the fishing season) are flexible. Opening time is based on preseason surveys for estimates of abundance and catch per unit of effort (CPUE) of shrimp, and time of closure is based on the trend of CPUE (kilograms per boat-days) during the fishing season or a final catch rate.

Although more than 16 different species of penaeid prawn are found in the Iranian waters of the Persian Gulf (Niamaimandi, 2006), only 5 species are presently of commercial

[1] FAO. 1981. Report of the third session of the Indian Ocean Fishery Commission for the development and management of the fishery resources of the Gulfs, Doha, Qatar, 28–30 September 1980. FAO Fish. Rep.FAO-FID-R247, 46 p.

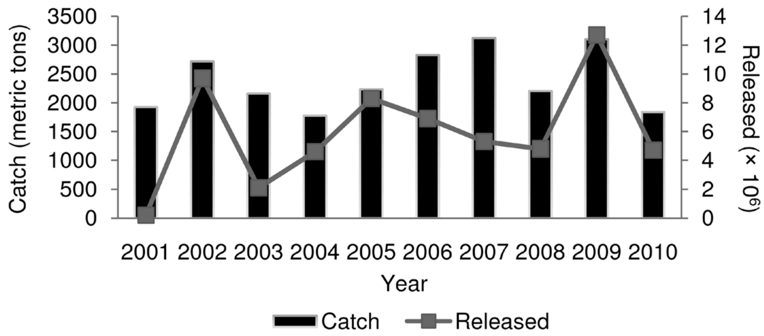

Figure 1

Annual total catches of banana prawn (*Fenneropenaeus merguiensis*), indicated in metric tons by the black bars, and numbers of this species released for stock enhancement (indicated by the line with squares) in waters of the Strait of Hormuz, along the coast of the Persian Gulf in Hormozgan Province, Iran, during 2001–2010.

interest. The banana prawn (*Fenneropenaeus merguiensis*) and Indian prawn (*F. indicus*), both found in the Strait of Hormuz (Hormozgan Province), and the green tiger prawn (*Penaeus semisulcatus*), found in the middle part of Iranian waters (Bushehr area), are the most commercially important shrimp stocks. The Jinga shrimp (*Metapenaeus affinis*) and the kiddi shrimp (*Parapenaeopsis stylifera*), the other important species, are distributed throughout the Iranian waters of the Persian Gulf.

The banana prawn in the Persian Gulf exhibits a fast growth rate and a short life span of around 15–18 months (Zarshenas[2]). The spawning season is very short (February to March) and is followed by a peak in abundance of postlarvae and juveniles present in the shallow coastal mangrove areas from mid-April to July, that then move from these nursery areas to deeper waters at the end of August. The annual catch of banana prawns during the period of 2001–2010 ranged from 1776 t in 2004 to 3122 t in 2009, fluctuating as much as 1000 t between years (Fig. 1).

The decline of prawn fishing in several countries (e.g., Japan, China, Mexico, Australia, and Kuwait) with growing human populations and demands for fishery products led to the development of stock enhancement techniques (Loneragan et al., 2006). The high commercial value of prawns, along with the noted stock decline in the Persian Gulf, generated interest in developing stock enhancement procedures to improve the prawn fisheries. In the Persian Gulf region, Kuwait was the first country that started stock enhancement of shrimp, the green tiger prawn and the kuruma prawn (*Marsupenaeus japonicus*), during 1972–1978 (Farmer, 1981). In Iran, a stock enhancement effort that started in 1995 with the Indian prawn was located in the Persian Gulf along the coast of Hormozgan Province. Wild adult Indian prawns were captured from this area to use for brood stock in aquaculture. However, because of the importance of the banana prawn as a commercial species, stock enhancement of this prawn was started in 2001. During the 15 years of shrimp stock enhancement in Iranian waters of the Persian Gulf during 1995–2010, about 260 million juvenile prawns (mostly Indian prawns, banana prawns, and kuruma prawns) were released at sea.

The annual number of juvenile banana prawn released, as well as the catch of this species between 2001 and 2010, is shown in Figure 1. The mean number of juveniles released was 5.93 billion, and the mean annual catch recorded was 2392 t. Catch of the banana prawn has fluctuated between years during the period of 2001–2010. The lowest and highest levels of banana prawn catch were observed in 2004 (1776 t) and 2007 (3122 t), whereas the minimum and maximum numbers of prawn were released in 2001 (200,000) and 2009 (12.7 billion).

The objectives of this study were to determine the success of the banana prawn stock enhancement program and to evaluate the growth and movement of stocked prawns within the Hormozgan study area.

Materials and methods

The study area was located within the Strait of Hormuz (56°24′E and 27°06′N to 56°26′E and 26°55′N) along estuarine mangrove habitat where depths were <1–3 m (Fig. 2). Wild adult banana prawns were captured from Hormozgan waters and cultured in a pri-

[2] Zarshenas, A. 1991. Shrimp fishery in Hormozgan waters, 27 p. Iranian Fisheries Research Organization, Tehran, Iran. [In Persian.]

vate hatchery center. A florescent elastomeric liquid injection was used to mark 50,000 juvenile banana prawns weighing 1 g each. Injections were made just beneath the skin tissue along a straight path several millimeters long with a 1-cc insulin syringe and a 25-gauge needle (Neal, 1969). Marked prawns were held in fiberglass tanks for 48 hours to observe individuals that may have been injured during marking. Marked prawns were transported by small boats to the sea in fiberglass tanks. The release area was close to the hatchery (about 20 min in travel time by boat). The use of these tanks kept fluctuations in water temperatures from the farm to the release area low, so that the temperatures measured in both areas were similar. Prawns were released through the use of a pumping system.

The mortality rate that resulted from marking and handling of prawn was less than 3%. Dead and moribund prawns were removed before tagged prawns were released to the sea.To prohibit transfer of disease to wild prawn, some specimens of the juvenile cultured shrimps were randomly subsampled to test for the presence of white spot syndrome disease, and prawns were released when no disease was found. Before the release of prawns, the study area was investigated by gill net for shrimp predators; further, releases were made at night to reduce the threat of bird predation. Juvenile prawns were released in mangrove areas, which are nursery grounds of the banana prawn (Staples, 1985; Meager, 2003), in June and July 2010.

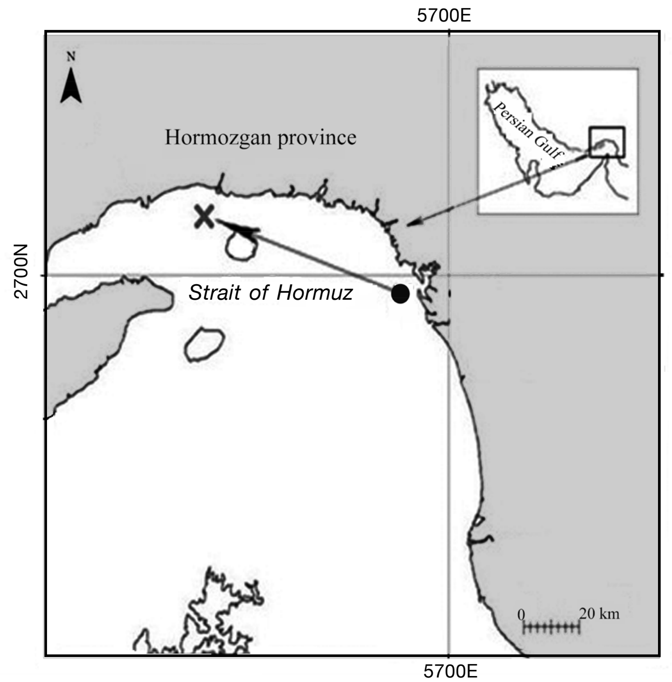

Figure 2

Map of the study area, showing the movement of 11 tagged and released banana prawns (*Fenneropenaeus merguiensis*) in 2010 between the release site (●) and recapture sites (✕) in coastal waters of Hormozgan Province, Iran, in the Strait of Hormuz, the opening that connects the Persian Gulf and the Arabian Sea.

Education and outreach efforts to raise public awareness of the release and recapture of prawns for this study included descriptive posters distributed to local persons. In addition, announcements were made in magazines and on national television broadcasts before, and during, the fishing season. A monetary reward program was established that paid the equivalent of USD 10 for the return of each marked prawn. This reward was twice as large as the reward offered in a successful study of tagged and recaptured sailfish (Hoolihan, 2003) that was conducted in the region during 2003–2004.

Costs were estimated for hatchery operation, grow-out, and release on the basis of data from private-sector hatcheries. The hatchery component comprised the brood stock and the hatched larvae. We estimated mean actual costs using the detailed prawn hatchery model, with options for the use of either wild or domesticated brood stock, developed by Preston et al. (1999). The total cost (Ωh) of operations from hatchery production to the point when prawn larvae were 15 days old was calculated with the following equation:

$$\Omega h = \eta Q^{\varphi}, \tag{1}$$

where η = cost per larvae for growth from nauplii to 15-day-old postlarvae (PL15);
Q = the number of larvae produced; and
φ = a parameter describing the economy of scale (i.e., when the scale of production increases, the unit cost of production will decrease). For the present study, φ was calculated at USD 0.0024 per PL15.

The total production (Tp) cost of grow-out of juveniles from PL15 to a weight of 1 g, including prawn feed, employee salaries, and pumping as a part of the operating cost, was calculated using Hannesson's (1993) formula, with some modifications:

$$Tp = (Cp) + (Be - Bi)\gamma\tau, \tag{2}$$

where Cp is the cost of pumping per square meter of raceway in the week, Bi and Be are the initial and end total biomasses of prawns, γ is the cost of feed per kilogram, and τ is the conversion ratio of food to growth in biomass. In the present study, 6.5 million PL15 were produced and 4.7 million juveniles ranging in average weight from 0.98 to 1.2 g were released into the study area. This weight of approximately 1 g was used for released prawns to reduce mortality. For the purpose

Table 1

Weights (g), numbers, and times of release of tagged juvenile banana prawns (*Fenneropenaeus merguiensis*) in estuaries in the Strait of Hormuz along the coast of the Persian Gulf in Hormozgan Province, Iran, during June–July 2010. The standard deviation (SD) of the mean weight is provided in parentheses.

	Mean weight (g)	Number released	Hour of release
	0.98	519,200	22-02
	1.10	494,542	24-02
	1.00	433,000	01-03
	1.40	1,098,332	11-02
	1.00	282,816	11-02
	0.89	733,578	18-02
	1.10	617,269	18-01
	1.20	521,664	20-03
Total	1.08 (0.1)	4,700,401	

of this study, capital investment of the hatchery was not considered. The total cost was the sum of hatchery production cost (Ωh) and juvenile production cost (Tp).

Growth increment (Gw) and growth rate (Gr) were calculated by using King's (2007) formulas:

$$Gw = Gf - Gi \tag{3}$$

$$Gr = w_{\mathrm{i}} / d_{\mathrm{t}}, \tag{4}$$

where Gf and Gi = the average weight of released and recaptured prawns;
w_{i} = the change in weight between times of release and recapture; and
d_{t} = the time (in days) between release and recapture.

In the study area, most of the fishing vessels were equipped with electronic geo-positioning systems (GPS), which provided accurate locations of recaptures. GPS information for the release and recapture location was used to estimate days at liberty, movement rate, and distance traveled for recaptured prawns. The distance between release and recapture locations was calculated as a straight line between the 2 locations.

Results

Of the 50,000 prawns that were marked and released overall, 11 (0.022%) were recaptured. The majority of these prawns were reported by local fishermen, and a few were observed by employees in local processing plants.

During this study in 2010, more than 4.7 million banana prawns, each 1 g in weight, were released in the mangrove estuaries in Hormozgan waters. The operation was carried out in June and July. Table 1 shows the numbers of prawns released at different times. The total production cost was approximately USD 0.004 g^{-1} prawn—or 4,700,000×0.004=USD 18,800.

On the basis of the comparison of the number of prawns released (4.7 million) and the recapture rate observed for tagged prawns (0.022%), about 1034 released prawns, with a mean weight of about 22.80 kg, were estimated to have been in the shrimp catch in Hormozgan in 2010.

The average local market price of prawns in 2010 was USD 3.440 kg^{-1}. Therefore, the total market value for the estimated number of released prawns in the catch in Hormozgan was USD 8670. The ratio of catch benefit to expenditures was 77.50:18,800=0.0041.

The juvenile prawns released in shallow waters (at depths of 1–2.5 m) on July 4–11 were recaptured at depths of 20–25 m, after reaching maturity, on Nov. 5–20 (a period of about 18 weeks). Tagged banana prawns moved in northwesterly direction from the release site at 56°56′E, 26°55′N to the recapture site at 56°24′E, 27°06′N in Hormozgan waters—a distance of 46 km (Fig. 2).The estimated rate of linear displacement for recaptured prawns was 310–330 m days^{-1}.

The mean age and weight of the 50,000 tagged prawns at release were 8.5 weeks old and 1.08 g (SD 0.1). The mean age and weight of the 11 recaptured prawns were 22 weeks and 22.06 g (SD 4.9). The differences in the weights of prawns between release and recapture were 16–26 g, and the differences in growth rates were 0.87–1.42 g weeks^{-1} (Table 2).

Discussion

In this study, certain factors, such as the choice of release sites, release season, and prawn handling, were carefully controlled to reduce the rate of mortality. In spite of a strong public awareness program, few prawns were recaptured. Success in recognizing individually marked marine organisms in the field requires observer training, mark visibility, and mark retention. Although previous studies indicated that the fluorescent elastomeric tag is a useful method for marking juvenile shrimp and fishes (Neal, 1969; Benton and Lightner, 1972; Frederick, 1997), problems with this method in our study may have contributed to the low recapture rate. For example, growth of tissue adjacent to the elastomeric mark reduced visibility of the mark in the recaptured prawns. Another contributing factor may have been a lack of prior training of observers that would have allowed them to identify marks.

In a study in China, other tagging methods (e.g., hanging tag brands, unilaterally extirpating eyestalks, and cutting uropods) were used and resulted in estimated recapture rates for juvenile fleshy prawns (*Fenneropenaeus chinensis*) from 0.001% to 1.510%. Such low recapture percentages likely were affected by tag shedding, death of tagged individuals by mechanical injury, and regeneration of the uropod (Wang

Table 2

A comparison of the growth of 11 banana prawns (*Fenneropenaeus merguiensis*) that were released and recaptured in waters of the Strait of Hormuz, along the coast of the Persian Gulf in Hormozgan Province, Iran, in 2010. *Gw*=growth increment, or change in weight (g) from release to recapture; *Gr*=growth rate (g weeks^{-1}); CL=carapace length (mm); and *W*=weight (g).

Released shrimp		Recaptured shrimp			
CL (mm)	*W* (g)	CL (mm)	*W* (g)	*Gw* (g)	*Gr* (g weeks^{-1})
13.95	1.2	28.57	17.4	16.2	0.88
13.95	1.2	28.63	17.5	16.3	0.88
12.90	1.2	28.63	17.5	16.3	0.88
12.95	1.2	28.63	17.5	16.3	0.88
13.95	1.2	29.57	17.5	16.3	0.88
13.00	1.1	29.57	19.1	18.0	1.02
12.50	1.0	33.69	27.2	26.1	1.41
11.55	1.0	33.69	27.2	26.3	1.42
13.90	1.1	33.69	27.2	16.1	0.87
13.95	1.1	33.74	27.3	16.2	0.88
13.80	1.1	33.74	27.3	16.2	0.88

et al., 2006). The similarly low recapture percentages observed in our study may also have been affected by the first 2 of those factors.

The low number of recaptured prawns identified in our study makes extrapolation of contribution of released prawns to the total catch tentative. The calculated contribution derived from the 11 recaptured prawns that were reported must be considered a minimum estimate because other tagged prawns may have been recaptured but not recognized or reported. However, the extremely low number of recaptured prawns that was reported gives no evidence that the contribution of released prawns to the total catch was profitable at the study area in 2010.

In this study in Hormozgan waters, banana prawn juveniles moved from shallow mangrove estuaries to deeper waters. The movement of juvenile banana prawns from mangrove habitat to offshore waters has been described already in different regions (Rothlisberg et al., 1985; Staples and Vance, 1985; Vance et al., 1996). Although the rate of recapture of marked prawns, at 0.022%, is too small to allow for making well-supported inferences, our findings show that the seasonal movement of the banana prawn is from inshore to offshore areas. The results of this study indicate that the banana prawn is not highly migratory and that recaptured prawn were caught mostly within 46 km of their release location, despite a period of liberty of 126 days.

Frusher (1985) reported that banana prawns in the northern Gulf of Papua (Papua New Guinea) exhibited maximum movements of 167 km for males and 190 km for females. The majority of all recaptured banana prawns exhibited rates of movement of less than 500 m days^{-1}. A comparison of the movement of banana prawn in our study in Iranian waters and in the Frusher (1985) study in Papua New Guinea indicates that this species migrates over greater distances during its entire life cycle than it does in the limited time of our study and that the number of recaptured shrimp might have been greater if the fishing season had been longer.

The main goal of the stock enhancement program for management of the prawn fishery in Iran was to increase the biomass of banana prawns. Management goals in most fisheries require accurate catch data, abundance estimates, measures of genetic diversity, and estimates of enhancement costs, as well as on a fisherman's willingness to pay and on the monitoring of conflicts (Lorenzen et al., 2010). Release of cultured juveniles would not be effective if there is insufficient nursery habitat to support them (Loneragan et al., 2004; Hamasaki and Kitada, 2006). In our study, the percentage of recaptured prawns did not support the economic feasibility of this type of release operation. An increase in total prawn catch due to the release of shrimp was estimated to account for about 2.5 t, a low proportion (<1%) of total catch. The difference between costs and revenue indicates that the stock enhancement program was not profitable, with a ratio of catch benefit to expenditures of 0.0041. This ratio would undoubtedly be reduced further if capital expenditures were considered.

The economic findings from stock enhancement reported from other areas indicate varying degrees of success. A shrimp stock enhancement program for the giant tiger prawn (*Penaeus monodon*) in a periodically enclosed lagoon of Sri Lanka was reported to be economically feasible and successful in increasing catches (Davenport et al., 1999). Despite a long history of prawn stock enhancement in Japan and China, economic reports on efforts there do not indicate a profitable experience in all instances. For example, only 5 out of 40 attempts at stock enhancement of the kuruma prawn in Japan proved economically profitable (Loneragan et al., 2006). In evaluations of the bioeconomics of stock enhancement programs for the fleshy prawn in China, cost-benefit ratios of 1:5.2, 1:7.8, and 1:8.5 were reported (Xu et al., 1997; Wang et al., 2006). However, it was not clear what costs were included in these calculations or whether these cost-benefit ratios provided accurate estimates of the real economic returns from stock enhancement (Loneragan et al., 2006).

The results of our study on the stock enhancement of the banana prawn in the Persian Gulf are limited. Further studies are essential to clarify the economical feasibility and biological justification of shrimp stock enhancement programs in this area. Marking in multiple locations with multiple colors and different sizes may provide a better evaluation of stock enhancement operations. Additional studies are needed to assess potential release sites at nursery grounds in this area, to determine optimum size at release, and to improve tagging methods. Hatchery practices may also introduce deleterious effects on the genetic makeup of released stock and, therefore, threaten the wild population. Such effects may range from mild, or undetectable, to severe (Ward, 2006). For future studies in the Persian Gulf area, it would be beneficial to determine and monitor the genetic structure of both wild prawn populations and populations held in captivity before release and throughout the study period. Experimental studies of the effects of other factors, such as the size of prawn at release (different sizes could be released), time of year of release, and the fitness of released prawns before release, also would give information that could increase the probability of success.

Although attempts at prawn stock enhancement in the Persian Gulf by the Iran Fisheries Organization occurred over the 15-year period of 1995–2010, the results of this activity have not been previously documented. The study described here investigated the economic return of the stock enhancement effort for one year only, 2010.

In general, the model used in this study estimated that it would require about 200,000 juveniles, each about 1 g in weight, to produce 1 t of additional catch for the total catch of wild banana prawns. Therefore, 200 million juveniles would be needed to produce an additional catch of 100 t. Some of production costs, such as capital investment, are not fully known and were not included in the model used in this study. These expenses would increase the estimates of the cost of production. On the basis of the market price for banana prawn (USD 3.440 kg^{-1}), the costs of juvenile production (USD 0.004 g^{-1} prawn), and our analysis of 2010 data, it is clear that stock enhancement of this species in Iran is not profitable.

Acknowledgments

This study was funded by the United Nations Compensation Commission and Iranian Fisheries Research Institute. The authors wish to thank K. Aeenjamshid for their assistance with equipment and field work and M. Momeni, M. Darvishi, K. Khajehnoori, I. Ghaeeni, and the staffs of the Persian Gulf and Oman Sea Ecological Research Institute, Hormozgan branch of the Iran Fisheries Organization, and Pars Abzistan Co. for participation in the tagging program and use of their facility.

Literature cited

Benton, R. C, and D. V. Lightner.
1972. Spray-marking juvenile shrimp with granular fluorescent pigment. Contrib. Mar. Sci. 16:65–69.

Davenport, J., S. U. K. Ekarante, S. A. Walgama, D. Lee, and J. M. Hills.
1999. Successful stock enhancement of a lagoon prawn fishery at Rekawa, Sri Lanka using cultured post-larvae of penaeid shrimp. Aquaculture 180:65–78. doi: 10.1016/S0044-8486(99)00141-6.

Farmer, A. S. D.
1981. Historical review of the Kuwait shrimp culture project. Kuwait Bull. Mar. Sci. 2:3–9.

Frederick, J. L.
1997. Evaluation of fluorescent elastomer injection as a method for marking small fish. Bull. Mar. Sci. 61:399–408

Frusher, S. D.
1985. The distribution and abundance of juvenile penaeid prawns in the northern Gulf of Papua, Papua New Guinea, with particular reference to *Penaeus merguiensis* (De Man). *In* Second Australian National Prawn Seminar (P. C. Rothisberg, B. J. Hill, and D. J. Staples, eds.); Kooralbyn, 22–26 October 1984., p. 65–72. NPS2, Cleveland, Australia.

Hannesson, R.
1993. Bioeconomic analysis of fisheries, 138 p. Fishing News Books, Oxford, UK.

Hamasaki, K., and S. Kitada.
2006. A review of kumura prawn *Penaeus japonicus* stock enhancement in Japan. Fish. Res. 80:80–90. doi: 10.1016/j.fishres.2006.03.018.

Hoolihan, J.
2003. Sailfish movement in the Arabian Gulf: a summary of tagging efforts. Mar. Freshw. Res. 54:509–513. doi: 10.1071/MF01252.

King, M.
2007. Fisheries biology, assessment and management, 2nd ed., 382 p. Blackwell Pub., Oxford, UK.

Loneragan, N. R., P. J. Crocos, R. M. Barnard, R. R. McCulloch, J. W. Penn, R. D. Ward, and P. C. Rothlisberg.
2004. An approach to evaluating the potential for stock enhancement of brown tiger prawns (*Penaeus esculentus*

Haswell) in Exmouth Gulf, Western Australia. *In* Stock enhancement and sea ranching: development, pitfalls and opportunities, 2nd ed. (K. M. Leber, S. Kitada, H. L. Blankenship, and T. Svasand, eds.),p. 444–464. Blackwell Publ., Oxford, UK.

Loneragan, N. R., Y. Yimin, R. A. Kenyon, and M. D. E. Haywood.
2006. New directions for research in prawn (shrimp) stock enhancement and the use of models in providing directions for research. Fish. Res. 80:91–100. doi: 10.1016/j.fishres.2006.03.014.

Lorenzen, K., K. M. Leber, and H. L. Blankenship.
2010. Responsible approach to marine stock enhancement: an update. Rev. Fish. Sci. 18:189–210. doi: 10.1080/10641262.2010.491564.

Meager, J. J.
2003. The microhabitat distribution of juvenile banana prawns, *Penaeus merguiensis* de Man and processes affecting their distribution and abundance, Ph.D. thesis, 221 p. Queensland Univ. Technol., Brisbane, Australia.

Neal, R. A.
1969. Methods of marking shrimp. FAO Rep. 57(3): 1149–1165.

Niamaimandi, N.
2006. Bio-dynamics and life cycle of shrimp (*Penaeus semisulcatus* de Haan), in Bushehr coastal waters of the Persian Gulf. Ph.D. thesis, 206 p. Univ. Putra Malaysia, Kuala Lumpur, Malaysia.

Preston, N. P., D. C. Brennan, and P. J. Crocos.
1999. Comparative costs of postlarval production from wild or domesticated Kuruma shrimp, *Penaeus japonicus* (Bate), broodstock. Aquacult. Res. 30:191–197. doi: 10.1046/j.1365-2109.1999.00306.x.

Rothlisberg, P. C., D. J. Staples, and P. J. Crocos.
1985. A review of the life history of the banana prawn. *Penaeus merguiensis*, in the Gulf of Carpentaria. *In* Second Australian National Prawn Seminar; Kooralbyn, 22–26 October 1984 (P. C. Rothisberg, B. J. Hill, and D. J. Staples, eds.), p. 125–136. NPS2, Cleveland, Australia.

Staples, D. J.
1985. Habitat requirements of juvenile prawns. *In* Second Australian National Prawn Seminar; Kooralbyn, 22–26 October 1984 (P. C. Rothlisberg, B. J. Hill, and D. J. Staples, eds.), p. 52–55. NPS2, Cleveland, Australia.

Staples, D. J., and D. J. Vance.
1985. Short-term and long-term influences on the immigration of postlarval banana prawns *Penaeus merguiensis*, into a mangrove estuary of the Gulf of Carpentaria, Australia. Mar. Ecol. Prog. Ser. 23:15–29

Van Zalinge, N. P.
1984. The shrimp fisheries in the Gulf between Iran and the Arabian Peninsula. *In* Penaeid shrimps—their biology and management (J. A. Gulland and B. J. Rothschild, eds.), p. 71–78. Fishing News Books, Farnham, England.

Vance, D. J., M. D. E. Haywood, D. S. Heales, R. A. Kenyon, N. R. Loneragan, and P. C. Pendrey.
1996. How far do prawns and fish move into mangroves? Distribution of juvenile banana prawns, *Penaeus merguiensis* and fish in a tropical mangrove forest in northern Australia. Mar. Ecol. Prog. Ser. 131:115–124. doi: 10.3354/meps131115.

Ward, R. D.
2006. The importance of identifying spatial population structure in restocking and stock enhancement programmes. Fish. Res. 80:9–18. doi: 10.1016/j.fishres.2006.03.009.

Wang, Q., Z. Zhuang, J. Deng, and Y. Ye.
2006. Stock enhancement and translocation of the shrimp *Penaeus chinensis* in China. Fish. Res. 80:67–79. doi: 10.1016/j.fishres.2006.03.015.

Xu, J., M. Xia, X. Ning, and C. P. Mathews.
1997. Stocking, enhancement, and mariculture of *Penaeus orientalis* and other species in Shanghai and Zhejiang Provinces, China. Mar. Fish. Rev. 59:8–14.