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# A New Era for Restocking, Stock Enhancement and Sea Ranching of Coastal Fisheries Resources

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*The growing number of countries investigating the potential for releasing cultured juveniles to augment coastal fisheries resulted in the First International Symposium on Stock Enhancement and Sea Ranching (ISSESR) in Norway in 1997. The 1st and 2nd ISSESR, in Japan in 2002, were instrumental in developing methods for mass production of environmentally fit juveniles and for releasing them in responsible ways. The 3rd ISSESR, held in the U.S.A. in 2006 (www.SeaRanching.org), ushered the discipline into a new era. The major advances included: (1) definitions of the various objectives for releasing cultured juveniles (restocking, stock enhancement, and sea ranching); (2) a framework for integrating releases within their fisheries management context, including tools for quantitative assessment; (3) a systematic, transparent, and stakeholder-participatory planning process to determine whether releases have a cost-effective role to play in managing a fishery; (4) a comprehensive case study (blue crabs in Chesapeake Bay) describing the multi-disciplinary approach needed to evaluate the potential benefits of releases; and (5) a suite of other lessons to guide stakeholders in evaluating the potential for and implementation of releases. The papers in this Special Issue of Reviews in Fisheries Science elaborate how restocking, stock enhancement and sea ranching programs can create synergies between aquaculture and some coastal fisheries to help meet the future demand for seafood and aid in restoring depleted stocks.*

**Keywords** fisheries management, integrated approach, stakeholder participation, multi-disciplinary research, lessons learned

## *BACKGROUND*

Managers of fisheries worldwide are searching for sustainable ways to restore depleted stocks and increase production to help meet the projected global demand for fish and shellfish, which is expected to increase by 1.5% each year over the coming decades (Delgardo et al., 2003). The consensus is that the future demand will need to be met by continued annual production from capture fisheries at the current level of around 80-100 million tonnes, with sustainable aquaculture making up the difference (Delgardo et al., 2003; FAO, 2004, 2006; Garcia and Grainger, 2005).

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Planning how to combine capture fisheries and aquaculture to meet future demand will be complex (Garcia and Grainger, 2005), but there is little disagreement about the basic measures needed to meet the call by the World Summit on Sustainable Development to restore capture fisheries to more productive levels. Incentives to reduce fishing capacity and effort, and protect and repair fish habitats, are required to rebuild spawning biomass and harness the increased larval supply (Pauly et al., 2002; FAO, 2003; Hilborn, 2007). Nevertheless, there is debate about the potential for recovery of capture fisheries and what restored fisheries would look like (Jackson et al., 2001; Pauly et al., 2002; FAO, 2004; Garcia and Grainger, 2005).

It is also evident that aquaculture will need to be integrated with capture fisheries to achieve harmonious co-development of the supply chain (Muir and Young, 1998; Garcia and Grainger,

2005). This is particularly true for coastal waters, which have considerable potential for aquaculture.

A promising synergy between capture fisheries and aquaculture is the opportunity to apply hatchery technology to restore and augment some coastal fisheries through the release of cultured juveniles. Similar interventions have long been used in the management of freshwater fisheries (Cowx, 1994). They were also attempted for marine finfish and lobsters by releasing eggs and larvae, commencing in the last half of the 19thcentury. However, these releases were abandoned in the mid 20th century when it was obvious they were ineffective (Richards and Edwards, 1986; Nicosia and Lavalli, 1999).

Interest in the release of cultured juveniles as a possible management tool for coastal fisheries was rekindled by the advent of methods for producing robust juveniles at reasonable cost. Japan spearheaded such initiatives in the 1970s and 1980s (Honma, 1993; Imamura, 1999). However, by the early 1990s, the number of other countries involved merited launching a series of international symposia to share experiences and promote responsible practice.

The First International Symposium on Stock Enhancement and Sea Ranching in Norway in 1997 (Howell et al., 1999) and the second symposium in Japan in 2002 (Leber et al., 2004) were important milestones in the development of the emerging discipline. Other dedicated scientific conferences and reviews have also helped advance the science for releasing a wide range of valuable coastal species (Blankenship and Leber, 1995; Munro and Bell, 1997; Travis et al., 1998; FAO, 1999; Svåsand et al., 2000; Blaxter, 2000; Caddy and Defeo, 2003; Molony et al., 2003; Mustafa, 2003; Bartley and Leber, 2004; Bell et al., 2005, 2006).

Not surprisingly, the focus so far has been on developing methods for mass-producing environmentally fit juveniles and releasing them in ways in which they survive well without affecting the ecosystem or genetic diversity of wild stocks. Overall, it is pleasing to see that many aspects of the call for responsible practice by Blankenship and Leber (1995) have now been adopted. However, the emphasis on developing the technology has been at the expense of determining how and when to apply it. In particular, too little attention has been paid to defining the exact objectives of producing and releasing juveniles (Loneragan et al., 2004; Bell et al., 2005, 2006). In many cases, releases have been driven from a production imperative rather than from a fisheries management perspective (Leber, 2002; Lorenzen, 2008). As a result, few releases of cultured juveniles have helped to optimize production from coastal fisheries resources. The most celebrated exception is the stock enhancement of scallops in Japan (Ventilla, 1982; Uki, 2006), although similar success stories are also emerging from China for shrimp, scallops, and sea cucumbers (Lovatelli et al., 2004; Wang et al., 2006a, 2006b).

The Third International Symposium on Stock Enhancement and Sea Ranching (3rd ISSESR), hosted by NOAA in the United States in September 2006, was instrumental in highlighting seven themes that will help to take the development of restocking, stock enhancement, and sea ranching to the next level: (1) identifying the potential roles of releases of cultured juveniles in fisheries management; (2) determining whether releases add value to other forms of management; (3) giving increased prominence to socioeconomic issues; (4) developing optimal release strategies; (5) implementing measures to minimize interactions between wild and released animals; (6) gaining biological insights from releases of cultured juveniles to improve other aspects of fisheries management; and (7) recognizing and learning from arenas of progress.

Here we briefly outline the main issues and advances stemming from the papers and posters presented at the 3rd ISSESR and the ensuing discussions. In doing so, we have also drawn on relevant recent literature.

## *A CURRENT WEAKNESS*

As the range of papers in this Special Issue demonstrates, the 3rd ISSESR showcased many applications for the release of cultured juveniles into coastal waters. But the meeting also exposed a weakness typical of any new field of research and development—the lack of widely accepted definitions. At the 3rd ISSESR, there was confusion in the use of terms for the different objectives of releasing juveniles. This needs to be corrected so that those seeking to learn from past experience can find information directly relevant to their objective. As it stands, the terms "stocking," "restocking," "stock enhancement," "supplementation," "sea ranching," "sea farming," "reseeding," "culture-based fisheries," or just "enhancement," are often used interchangeably to describe management interventions in coastal fisheries as disparate as (1) restoring spawning biomass to target levels where severe overfishing has occurred, (2) increasing the supply of juveniles to stabilize production, and (3) increasing yields through "put, grow, and take" operations. The picture is confused further by recent trends to call the aquaculture of tuna in large sea cages "sea ranching."

We offer the following definitions for the three main objectives of releasing cultured juveniles of indigenous species to help manage coastal fisheries.

**Restocking**—*The release of cultured juveniles into wild population(s) to restore severely depleted spawning biomass to a level where it can once again provide regular, substantial yields*. This may also involve reestablishing a commercial species where it is locally extinct due to overfishing, or release of juveniles reared in "conservation hatcheries" to help restore endangered or threatened species.

**Stock enhancement**—*The release of cultured juveniles into wild population(s) to augment the natural supply of juveniles and optimize harvests by overcoming recruitment limitation*. Note that recruitment limitation is common for many coastal species with pelagic larvae in open ecosystems, even when spawning biomass is at the desired level (Doherty, 1999; Bell et al., 2005).

**Sea ranching**—*The release of cultured juveniles into unenclosed marine and estuarine environments for harvest at a larger size in "put, grow, and take" operations*. Note that the released animals are not expected to contribute to spawning biomass, although this can occur when the size at harvest exceeds the size at first maturity, or when not all the released animals are harvested.

Similar objectives and definitions also apply to freshwater fisheries, but our purpose here is to clarify the terminology for releases of cultured juveniles into coastal waters. We hope that these draft definitions will be discussed and revised as needed by the FAO Committee on Fisheries, and then added to, or combined with, definitions concerning the release of hatchery-reared juveniles into freshwater. Such interventions in freshwater fisheries have been underway for much longer than those in coastal waters and include the **stocking** of non-indigenous species (Cowx, 1994). None of the definitions we propose above apply to non-indigenous species. Any releases of introduced species to create fisheries, including those intended as "put, grow, and take" operations, will require separate definitions.

## *THE NEED FOR AN INTEGRATED APPROACH*

As important as it is to clarify this terminology and eventually to adopt one set of definitions that apply to both coastal and freshwater fisheries, we must not lose sight of the fact that the technical ability to engage in restocking, stock enhancement, and sea ranching is only one of the components that will determine whether these interventions prove useful to fisheries managers. The first of the two keynote addresses at the 3rd ISSESR (Lorenzen, 2008) reminded us that releases of cultured juveniles are often made into complex fisheries systems. To be effective, releases need to contribute to the biological, economic, social, and institutional management objectives of the fishery. Lorenzen (2008) outlines a framework for the integrated analysis of restocking, stock enhancement, and sea ranching within their fisheries management context. The framework takes a broad systems view of these interventions and gives equal emphasis to the dynamics of both biological and human components. It also links with new quantitative methods for evaluating the impacts of juvenile releases on fish stock dynamics (Lorenzen, 2005; Medley and Lorenzen, 2005). A logical outcome of the framework and approach described by Lorenzen (2008) is that investments in restocking and stock enhancement should not be made unless they are likely to add value to other forms of management.

Lorenzen (2008) also outlines a 5-step, systematic, transparent, and stakeholder-participatory planning process to determine whether releases of cultured juveniles have a cost-effective and socially beneficial role to play in managing a fishery. In brief, the steps in the process are (1) engage stakeholders and identify the nature and strength of their interactions; (2) understand the fishery system and identify development objectives and possible courses of action including releases of cultured juveniles; (3) conduct quantitative analysis of management options within the context of the fisheries system; (4) initiate intervention and monitoring, or discontinue if the benefits of releases are likely to be lower than those of alternative options; and (5) evaluate outcomes. A key ingredient of the process, from Step 2 onward, is the use of quantitative methods to assess the impacts of releases on stock dynamics (Lorenzen, 2005).

All previous approaches to restocking, stock enhancement, and sea ranching find a home in the process proposed by Lorenzen (2008), which gives equal emphasis to stakeholder action, innovation, rigorous assessment, and evaluation. For example, Blankenship and Leber's (1995) responsible approach will help guide Steps 1–3. Similarly, the need to make releases at the scale of self-replenishing populations and to model whether they will be more effective than other interventions, emphasized by Bell et al. (2005, 2006), also contribute to Steps 1–3.

By expanding the focus from technology to effective participation of stakeholders, integration, and adoption, Lorenzen (2008) has precipitated a sea-change in thinking about how and when to apply releases of cultured juveniles to improve the management of coastal fisheries. Clearly, a multi-disciplinary team of scientists and analysts will be needed to guide stakeholders (see below), but it is the stakeholders, not analysts, who should make the decisions. Ultimately, the actions of stakeholders must and will drive restocking and stock enhancement projects (Lorenzen, 2008; Tringali et al., 2008a; Zohar et al., 2008; see also Garaway et al., 2006).

Sea ranching projects are simpler—they operate at various scales where participants have exclusive access rights to the necessary habitat (Becker et al., 2008). For sea ranching, analysis will focus on determining whether the values of harvests are likely to deliver the desired profits. Such analyses will depend heavily on reliable estimates of the cost of juveniles, survival rates to harvest size, recapture rates, and various "externalities" (Arnason, 2008).

## *SCALE AND DIVERSITY OF RESEARCH REQUIRED: A CASE STUDY*

The second keynote address (Zohar et al., 2008) highlighted the range of activities needed to implement Steps 1–3 in the process outlined by Lorenzen (2008). The task set before Zohar et al. (2008) was to assist stakeholders to assess whether releases of hatchery-reared juveniles can help restore the spawning biomass of blue crabs in Chesapeake Bay, which has decreased by 84% since 1988. Other appropriate management measures have arrested the decline but have not rebuilt the number of spawning crabs.

Zohar et al. (2008) provide us with at least four vital lessons. First, the life histories of coastal species can be complex, and restocking and stock enhancement programs must be designed so that released juveniles can complete their life cycle and

contribute to spawning biomass. Second, large investments in a multi-disciplinary team are needed to elucidate all the important components of life history and develop technology for releases at a meaningful scale in a responsible way. Third, restocking and stock enhancement programs must be guided by thorough science that leads to optimal release strategies and dependable assessment of success. Fourth, release programs can sometimes improve on natural production cycles. By producing juveniles 3–4 months earlier in the year than occurs naturally, female blue crabs released by Zohar et al. (2008) contributed to the spawning stock the same year they were released, whereas wild crabs did not reach the spawning ground until the following year. Therefore, some early releases of cultured juveniles have potential to fast-track recovery compared to other management measures. Zohar et al. (2008) also demonstrate the importance of integrating releases with adequate and science-based management strategies to protect the released and wild crabs until they reproduce.

## *OTHER LESSONS LEARNED*

The 41 other papers in this volume, and additional presentations at the 3rd ISSESR (www.SeaRanching.org), also help to usher in a new understanding of the potential applications of restocking, stock enhancement, and sea ranching, and when and how to implement them. Here we summarize the other valuable lessons and trends, in addition to those already described for the two keynote addresses, to emerge from the 3rd ISSESR and recent literature. These lessons and trends are arranged under the themes of the 3rd ISSESR.

### *Restocking, Stock Enhancement and Sea Ranching Systems, and Their Role in Fisheries Management*

- Creative "win-win" approaches can be developed to meet the twin objectives of replenishing fisheries and generating income (Juinio-Meñez et al., 2008).
- Profitable sea ranching is now developing at a variety of scales (Cooper and Hill, 2006; Wang et al., 2006a; Becker et al., 2008; Lu et al., 2008; see also Roberts et al., 2007).
- Involvement of stakeholders can be facilitated by creating advisory groups as an integral part of the adaptive management process. Such advisory groups have been instrumental in identifying ineffective stock enhancement programs (Tringali et al., 2008a).
- Mismatches in larval production and environmentally mediated food availability may afford an opportunity for restocking, stock enhancement, and sea ranching if releases of hatchery-reared larvae are timed and located to coincide with high densities of their prey (Støttrup et al., 2008) and/or protected for short periods using containment enclosures (Arnold, 2008).
- Releases of cultured juveniles cannot be used to overcome downturns in the natural productivity of fisheries (Arbuckle, 2006).
- Costs of restocking and stock enhancement can be reduced by "piggy-backing" production of juveniles for release on existing aquaculture (Le Vay et al., 2008; see also Wang et al., 2006b, and Hamasaki and Kitada, 2006).
- Restocking of some species can be done effectively simply by aggregating adults in no-take zones to form a viable spawning biomass (Davis et al., 2006; see also Bell et al., 2005).
- Yields and market traits of some species can be increased by translocating individuals to more productive habitat (Gardner and van Putten, 2008a, 2008b); however, the success of translocations can depend on the life history stage involved (Eggleston et al., 2008).
- There are no generic methods for restocking, stock enhancement, and sea ranching—each proposal requires targeted research and rigorous assessment (Bartley and Bell, 2008).

### *Ensuring that Releases of Cultured Juveniles Add Value to Other Forms of Management*

- Restocking and stock enhancement interventions need to be applied at the scale of self-replenishing populations or the appropriate components of a metapopulation—this puts the onus on managers to understand the population structure of the fishery (Lipcius et al., 2008; Tringali et al., 2008b; see also Bartley and Bell, 2008).
- Releases of juveniles for restocking and stock enhancement must be supported by appropriate management (Aguilar et al., 2008; see also Bell et al., 2005).
- Co-management facilitates integration of releases of cultured juveniles and habitat restoration (Le Vay et al., 2008).
- Development of cost-effective tagging methods is critical to the efficient evaluation of releases (Bartley and Bell, 2008; Potter et al., 2008; see also Blankenship and Leber, 1995; Loneragan et al., 2004; Brennan et al., 2005; Hamaski and Kitada, 2006; Tringali, 2006).
- Surveys of productivity in targeted release areas, followed by model-based estimation of the number of released animals that can be supported, provides a sound basis for determining the scale of releases (Taylor and Suthers, 2008; see also Arbuckle, 2006).

### *Institutional and Socioeconomic Issues*

- Incentives that confer harvesting rights to those who invest in the production and release of juveniles are needed to establish sustainable restocking, stock enhancement, and sea ranching programs (Arbuckle, 2006; James, 2006; Arnason, 2008).
- Successful stock enhancement and sea ranching programs are often run by cooperatives and the private sector

(Arbuckle, 2006; Cooper and Hill, 2006, James, 2006; Wang et al., 2006a; Becker et al., 2008; Tomiyama et al., 2008; see also Arbuckle and Metzger, 2000; Uki, 2006; Wang et al., 2006b).
- Access to large areas needs to be negotiated for stock enhancement of some species (Arbuckle, 2006; Bartley and Bell, 2008).
- Release programs can raise awareness of the importance of fishery management among stakeholders, resulting in increased willingness to accept fishing effort controls. However, such synergies can decline when releases cease (Tomiyama et al., 2008).
- The costs and timeframes involved in restocking programs can be prohibitive; therefore, the onus is on stakeholders to ensure that populations are not reduced to levels where they require restocking (Bartley and Bell, 2008).
- Translocation of animals can increase the profits from fishing substantially, and modeling can indicate the locations where gains in production can be expected and translocations are likely to be cost-effective (Gardner and Van Putten, 2008a, 2008b).
- Restocking, stock enhancement, and sea ranching invariably have economic and social consequences beyond those relevant to the intended beneficiaries. Such "externalities" are often associated with economically unwise choices about the magnitudes of releases and lack of changes to conventional management of fisheries. An appropriate mix of taxes and subsidies could theoretically correct the problem of externalities, but individual property rights offer a better solution (Arnason, 2008).
- Yields from recaptures and economic efficiency can vary greatly among and within restocking, stock enhancement, and sea ranching projects (Hamaski and Kitada, 2006, 2008) and between years (Arbuckle, 2006).

### *Release Strategies*

- Field and laboratory experiments are valuable for identifying variables that affect survival after release (Eggleston et al., 2008; Hines et al., 2008; Oliver et al., 2008; Shimizu et al., 2008), but small-scale experiments to test methods for releasing juveniles can give misleading results (Purcell and Simutoga, 2008).
- Releases need to be made in ways that do not cause density-dependent mortality among the cultured animals or replacement of wild juveniles (Brennan et al., 2008; Seitz et al., 2008; see also Loneragan et al., 2004; Hamasaki and Kitada, 2006; Wang et al., 2006a).
- Releases of cultured juveniles will be ineffective where there is insufficient nursery habitat to support them (Loneragan et al., 2004; Hamasaki and Kitada, 2006; Kitada and Kishino, 2006).
- Good survival of released juveniles at one site is no guarantee that the methods can be transferred to other sites (Brennan et al., 2008; Gardner and van Putten, 2008a; Nakajima et al., 2008; Purcell and Simutoga, 2008).
- Size at release affects economic efficiency (Obata et al., 2008); however, optimal size at release can vary depending on the season of release (Johnson et al., 2008).
- Where effective reproduction of the cultured animals is an objective, care is needed to release juveniles at times and places where they can eventually spawn effectively (Hines et al., 2008; Lipcius et al., 2008; Zohar et al., 2008).
- Predation is the greatest hurdle to survival of released juveniles (Hines et al., 2008; Støttrup et al., 2008; see also Bell et al., 2005).
- The fitness of hatchery-reared juveniles compared to wild counterparts should be investigated (Le Vay et al., 2008; Ogawa et al., 2008; Potter et al., 2008; Shimizu et al., 2008), but conditioning of cultured juveniles to improve initial survival is not always necessary (Agnalt et al., 2006; Young et al., 2008).
- Yields of some species can be increased by providing suitable settlement habitat and redistributing juveniles from areas of heavy settlement (Arbuckle, 2006; Le Vay et al., 2008; see also Bell et al., 2005).
- Construction of artificial habitats and restoration of lost or degraded areas can increase the carrying capacity for released cultured juveniles (Wang et al., 2006a; Le Vay et al., 2008).
- On-site acclimation of target species prior to release may attract predators (Fairchild et al., 2008).

### *Interactions between Wild and Released Stocks*

- Well-established protocols for optimizing effective population size, i.e., using sufficient broodstock, choosing the genetically correct broodstock, and avoiding inadvertent selection among broodstock, are needed to produce cultured juveniles with gene frequencies representative of the wild population (De Innocentiis et al., 2008; see also Ward, 2006).
- Large-scale releases of hatchery-reared juveniles have potential to affect genetic diversity of wild populations (Bartley and Bell, 2008; Hara et al., 2008; see also Wang et al., 2006b).
- Eggs originating from hatchery-reared animals (including those held in cages) contribute to replenishment of the local wild population (Jørstad et al., 2008; Juinio-Meñez et al., 2008).
- Use of wild broodstock to produce cultured juveniles reduces the risk of environmentally induced sex reversal in some released species (Kanaiwa and Harada, 2008).
- Use of risk analysis frameworks can greatly reduce the chances of spreading diseases as a result of releasing cultured juveniles in the wild (Bartley et al., 2006).
- Decisions about stocking magnitude become clearer when density, biomass, and distribution of the target population are monitored both prior to and following hatchery releases (Becker et al., 2008; Brennan et al., 2008). Successive

monitoring of biomass and stocking can help reveal the productive capacity of the release site.

### *Biological Insights from Releases of Hatchery-Reared Juveniles*

- Restocking programs help quantify spawning biomass (Potter et al., 2008).
- Releases of cultured juveniles and monitoring their survival and growth help develop an understanding of the carrying capacity of coastal environments for target species (Brennan et al., 2008; Ogawa et al., 2008; Seitz et al., 2008; Sparrevohn and Støttrup, 2008).
- Release programs have provided the motivation to identify critical habitats for target species (Davis et al., 2006; Neidig et al., 2006; Shane et al., 2006; see also Taylor et al., 2006). Such information aids the design of reserves to protect nursery habitats and spawning areas, and other forms of spatial management.
- Releases of cultured juveniles have provided information on movement patterns, dispersal, and site fidelity (Okouchi and Nakagawa, 2006; Brennan et al., 2008; Johnson et al., 2008; Pedersen et al., 2008), which can also be important to effective spatial management.

## *ARENAS OF PROGRESS*

Apart from the many lessons above and some others listed by Bartley and Bell (2008), which illustrate where progress has been made and the recent technological developments in hatcheries, tagging methods and application of genetic principles and tools, the outstanding recent arena of progress is in China. There, major companies employing thousands of people are engaged in sea ranching of sea cucumbers, scallops, abalone, and shrimp (Wang et al., 2006a, 2006b; Lu et al., 2008). Large-scale restocking and stock enhancement projects are also underway in China (Cheng et al., 2008; Lu et al., 2008). Significant central and local government funding is often provided to develop and strengthen these initiatives.

Progress is also being made elsewhere in developing hatchery production of juveniles of valuable species (Masuma et al., 2008; Okamoto, 2008), and in developing countries (Hoang et al., 2006; Juinio-Meñez et al., 2008; Le Vay et al., 2008; Okuzawa et al., 2008; see also Gomez and Mingoa-Licuanan, 2006; Primavera et al., 2006).

## *CONCLUDING REMARKS*

Taken together, the lessons emerging from the 3rd ISSESR and the recent literature are taking our discipline into a new era. Although there is much that we still do not know, stakeholders in coastal fisheries now have a broad array of technology and integrated approaches to help improve yields of some of the natural resources under their control. Methods for cost-effective production and release of cultured juveniles in a responsible way are now available. There is a clear understanding of the different reasons why such releases may be required and of the objective analyses needed to determine whether releases will add value to other forms of management. The need to target the release of juveniles for restocking and stock enhancement at self-replenishing populations, or the appropriate components of metapopulations, is now appreciated. Approaches for estimating the economic viability of restocking, stock enhancement and sea ranching have been documented. And, most importantly, a framework for integrating the biotechnical aspects of releases within a fisheries management context with a systematic, transparent, and stakeholder-participatory planning process, supported by quantitative assessment tools, has been developed.

Where appropriate incentives exist to invest in production of juveniles, we can expect to see releases of juveniles used to restore and increase yields of selected coastal fisheries in a variety of creative ways. In addition to the release of cultured juveniles in restocking, stock enhancement and sea ranching operations, the diversity of approaches will include organizing cage culture to contribute to egg production, aggregating remnant wild adults in no-take zones, restoring nursery habitats and installing artificial habitats to harness a greater proportion of the natural larval supply, redistributing juveniles to prevent density-dependent mortality, and translocating adults to improve growth, reproduction, and market value. Several invertebrates have special appeal for many of these interventions owing to their sedentary nature, low position in the food chain, and high economic value.

As bottlenecks in survival of released juveniles are overcome and rights to harvest the released animals are negotiated, we predict that restocking, stock enhancement, and sea ranching will be used increasingly to create productive synergies between aquaculture and capture fisheries. Zoning of coastal areas to achieve the most parsimonious combination of capture fisheries, sea ranching, and aquaculture will then be needed to optimize production of seafood and employment. We look forward to seeing such management interventions presented and discussed at the 4th ISSESR to be held at Shanghai Fisheries University, China, in 2010.

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