THE 4TH INTERNATIONAL SYMPOSIUM ON STOCK ENHANCEMENT AND SEA RANCHING

As part of the 9th Asian Fisheries and Aquaculture Forum
Shanghai Ocean University
April 21 to 23, 2011

Book of abstracts for Oral and Poster presentations

Prepared by:
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Welcome to the
4th International Symposium on Stock Enhancement and Sea Ranching
part of the 9th Asian Fisheries and Aquaculture Forum
Shanghai Ocean University, April 21 to 23, 2011

The 4th International Symposium on Stock Enhancement and Sea Ranching is being held in China, a region where very large scale releases of cultured fishes and invertebrates are being made and have been made for the last 30 years. Large-scale releases highlight the need to understand the consequences for wild populations and ecosystem function so that releases can be designed and implemented to meet their objectives in a responsible way. Viable and responsible approaches that have met their objectives in the past may also need to be adapted to meet the challenges of changing climate and changing global economy. The Themes for the 4th ISSESR are being developed to take these major issues for restocking, stock enhancement and sea ranching into account. The Themes may be modified over time with feedback from the committee members and interested participants and after abstracts have been submitted. Currently, the Themes for the Symposium are:

A) The role of releases of cultured animals in fisheries management: integrative evaluation
B) Modelling and assessing the effectiveness of releases for fisheries management and conservation
C) Governance and the socio-economics of release programs
D) Developing optimal release strategies
E) Interactions among wild and released animals and the ecological and genetic implications
F) Enhanced knowledge on populations and ecosystems from releases of cultured animals
G) Adapting to change: climate, habitat and socio-economics.

The First and Second International Symposiums on Stock Enhancement and Sea Ranching in Norway in 1997 and Japan in 2002 were instrumental in highlighting the technology and approaches needed to release hatchery-reared juveniles in a responsible way.
The Third International Symposium was held in Seattle, USA in September 2006 and was a great success. It also provided the opportunity to refine the technologies needed to achieve responsible practice, and identify how our discipline is contributing to a better understanding of the biological processes that underpin fisheries. The peer-reviewed Proceedings were published in 2008 in Volume 16 (1-3) of Reviews in Fisheries Science.

We welcome you to the Shanghai Ocean University and the Fourth International Symposium of Stock Enhancement and Sea Ranching.

Professor Neil Loneragan,
Chair, International Scientific Committee
4th ISSESR
Director, Centre for Fish, Fisheries and
Aquatic Ecosystem Research,
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Dr WANG Qingyin
Chair, National Steering Committee,
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Director-General,
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Keynote speakers and overview speaker

Overview of current and future perspectives for China
Mr ZHAO Xing-wu (Director of Fisheries Bureau, Ministry of Agriculture, Beijing, China)
"Strengthen aquatic resource protection, enhance ecological culture construction and fisheries sustainable development - China's aquatic resource protection, actions and achievements"

Keynote: Comprehensive case studies:
Dr Anson Hines (Smithsonian Environmental Research Center, Unites States) and Professor Cheng Yongxu (Shanghai Ocean University, China)
"Strategic mixing of fishery management, aquaculture and stock enhancement: Comparison of case studies of the Chesapeake blue crab (Callinectes sapidus) in the United States and the swimmer crab (Portunus trituberculatus) in three provinces of China"

Keynote: Genetic interactions between cultured and wild stock:
Dr Shuichi Kitada (Tokyo University of Marine Science and Technology, Japan)
"Rearing and genetic effects on fitness of artificially-produced animals in the wild: empirical evaluation of large-scale fishery stock enhancement programs"

Keynote: Perspectives on responsible approaches
Dr Ken Leber (Mote Marine Laboratories, United States)
Perspectives on 'A Responsible Approach to Marine Stock Enhancement: An Update': better integration with fishery assessment, management, and stakeholder involvement

Keynote: Evaulating the effectiveness of releases
Professor Kai Lorenzen (Florida University, United States)
"Quantitative approaches to evaluating the contribution of release programs to fisheries management goals"

Brief biographies of keynote speakers

Dr Anson H. Hines (Smithsonian Environmental Research Center, Unites States) **and Dr Cheng Yongxu** (Shanghai Ocean University, China)

"Strategic mixing of fishery management, aquaculture and stock enhancement: Comparison of case studies of the Chesapeake blue crab (Callinectes sapidus) in the United States and the swimmer crab (Portunus trituberculatus) in three provinces of China"

Dr Anson Hines

Dr. Anson "Tuck" Hines is the Director of the Smithsonian Environmental Research Center (SERC), a 1,000 ha located on Chesapeake Bay in Edgewater, Maryland, USA. He provides oversight and leadership of research, professional training and public education programs in global change, landscape ecology, ecosystems in coastal regions, and population & community ecology. Dr. Hines has a B.A. degree in Zoology from Pomona College and a Ph.D. in Zoology from the University of California at Berkeley. He has conducted research on coastal ecosystems in Chesapeake Bay, Florida, California, Alaska, Belize, Japan, and New Zealand. Dr. Hines has been project leader on a diverse array of research, including: effects of thermal discharges of coastal power plants; sea otters and kelp forest ecology; long-term ecological change in Chesapeake Bay; marine food web dynamics; predator-prey interactions; impacts of fisheries, aquaculture and fishery restoration; crustacean life histories; and biological invasions of coastal ecosystems. He has studied the biology of crabs around the world and is an expert on blue crabs. Over the past 10 years he has been a Principal Investigator for the Blue Crab Advanced Research Consortium to test the feasibility of responsible stock enhancement of the blue crab fishery in Chesapeake Bay. He has published more than 140 articles in technical journals and books. He has served as major advisor for 20 Post-doctoral fellows, 10 Ph.D. students and 9 M.S. students, and mentor for more than 125 undergraduate Interns.

Dr Cheng Yongxu

Dr Cheng Yongxu is Director of the Department of Nutrition and Physiology in the College of Aquaculture and Life Sciences, Shanghai Ocean University. Over 20 years, he has conducted research on the aquaculture of crab species, particularly their nutrition and reproduction and has published more than 150 papers. His research interests are: crab nutrition in relationship to their reproduction, growth and development (nutritional reproduction); the lipid nutrition of crab and its metabolic biochemistry, Reproductive biology of crabs, and the mass culture of live food (rotifer, *Artermia*, *Cladocera*) for Aquaculture and its nutritional enrichment. His research on Chinese mitten crab *Eriocheir sinensis* has taken some important roles in improving the development of national aquaculture. Currently, he is focusing his research on the swimming crab *Portunus trituberculatus*, the third most important crab species produced by aquaculture in China. In 2009, he and his colleges successfully held the "International Symposium on Aquaculture, Biology and Management of commercially important Crabs-2009" (ISABMC-2009) at the Shanghai Ocean University. He is currently supervising one post-doctoral fellow, 3 Ph.D students and 18 MSc students.

Dr Shuichi Kitada (Tokyo University of Marine Science and Technology, Japan)
"Rearing and genetic effects on fitness of artificially-produced animals in the wild: empirical evaluation of large-scale fishery stock enhancement programs"

Dr. Shuichi Kitada is a Professor in the Department of Marine Biosciences, Tokyo University of Marine Science and Technology (TUMSAT), Japan, specializing in fishery resource enhancement and conservation. He teaches graduate and undergraduate courses in fish stock enhancement, ecological bioinformatics and conservation genetics. He has a B.A. degree in Fishery Science from Hokkaido University (1976) and a Ph.D. in Agriculture from the University of Tokyo (1991). He worked for the Japan Sea Farming Association, which subsequently merged with the Fishery Research Agency, for two decades in quantitative evaluation of effectiveness of marine stock enhancement programs. He authored "Stock enhancement assessment with Japan examples" in 2001, and coauthored "An Introduction to Biostatistics" with Sakutaro Yamada in 2004, and published over 100 peer reviewed articles. He has been a member of the Scientific Committee for the International Symposium on Stock Enhancement and Sea Ranching since 1996, and the scientific board of the Invasive Alien Act, Ministry of Environment. His current interest is to evaluate impacts of hatchery-reared animals and alien species on wild populations and statistical modeling for genetic data analyses. He has been leader of two research projects at TUMSAT; Conservation Genetics Group and Monitoring and Evaluation of Anthropological Impacts on Biodiversity. Dr. Kitada is an adjunct Professor at the Agricultural Bioinformatics Research Unit, Graduate School of Agricultural and Life Sciences, the University of Tokyo.

Dr Ken Leber (Mote Marine Laboratories, United States)
"Perspectives on 'A Responsible Approach to Marine Stock Enhancement: An Update': better integration with fishery assessment, management, and stakeholder involvement"

Dr. Ken Leber is the Director of the Center for Fisheries Enhancement at Mote Marine Laboratory, an independent, non-profit research institution established in 1955 and located on the Gulf of Mexico in Sarasota, Florida, USA. His specialty is fisheries ecology and marine stock enhancement. He also provides oversight and leadership of research on fisheries-habitat ecology. Dr. Leber has a B.S. degree in Biology from George Mason University, an M.S. in Biology from East Carolina University and a Ph.D. in marine ecology from Florida State University. He conducted research on predator-prey dynamics in seagrass meadows in coastal systems of Florida. Since 1988 he has focused much of his research on developing and evaluating marine stock enhancement, with particular emphasis on optimizing release strategies and evaluating hatchery-wild fish interactions. He started his stock-enhancement research program in Hawaii with striped mullet and Pacific threadfin. In 1995, he coauthored 'A responsible approach to marine stock enhancement' with Lee Blankenship. In 1996, he began research on red drum and common snook stock enhancement in Florida. His current focus includes expanding use of hatcheries to evaluate ecological questions about wild stock recruitment dynamics and density dependence. He has published more than 40 articles in scientific journals and books. He has served as advisor for 3 Post-doctoral fellows, 5 Ph.D. students and 4 M.S. students. Dr. Leber is an adjunct Professor in the Fisheries and Aquatic Sciences Program, School of Forest Resources and Conservation, University of Florida.

Dr Kai Lorenzen (University of Florida, United States)
"Quantitative approaches to evaluating the contribution of release programs to fisheries management goals"

Dr. Kai Lorenzen is Professor of Integrative Fisheries Science at the University of Florida, where he leads an interdisciplinary research program focusing on the role of supply-side interventions such as stock and habitat enhancement in fisheries management. He is best known for his work on the population dynamics and quantitative assessment of enhanced fisheries and for related research on size- and density-dependent processes in fish populations. Dr. Lorenzen has also developed an interdisciplinary framework for analyzing enhancement fisheries systems. With Lee Blankenship and Ken Leber he recently revised a set of guiding principles for the development or reform of stock enhancement programs known as the 'responsible approach'. Dr. Lorenzen holds a Master's degree in Biology with Mathematics from Kiel University (Germany) and a PhD in Applied Population Biology from the University of London. He worked as a fisheries development consultant, mostly in Asia, from 1992 to 1996. He joined the faculty of Imperial College London in 1997 and move to the University of Florida in 2010.

Abstracts of Overview and Keynote speakers

Mr ZHAO Xing-wu (Director of Fisheries Bureau, Ministry of Agriculture, Beijing, China)
Overview: "Strengthen aquatic resource protection, enhance ecological culture construction and fisheries sustainable development - China's aquatic resource protection, actions and achievements"

In this report, the Chinese policies on aquatic resource protection will be discussed, along with major stock enhancement release projects, protected areas for commercially important biological resources, mandatory moratorium periods, protection of endangered wild aquatic animals and aquatic ecosystem protection etc.. The economic, ecological and social achievements of aquatic resource protection will be summarized, and future trends and developments will be discussed.

Keynote: Strategic mixing of fishery management, aquaculture and stock enhancement: Case of the Chesapeake blue crab.
Anson H. Hines[1], Eric G. Johnson[1], Romuald N. Lipcius[2], Rochelle D. Seitz[2], Oded Zmora[3], Yonathan Zohar[3], David Eggleston[4], and Kenneth Leber[5].
[1]Smithosonian Environmental Institute, [2]Virginian Institute of Marine Science, [3]University of Maryland,[4]North Carolina State University, [5]Mote Marine Laboratory

Three main approaches are used in seafood production strategies: fishery management of wild stocks by regulating catch; aquaculture for directly consumable products; and stock enhancement or sea ranching that blends aquaculture with fishery management in open environments. How should these approaches be applied in strategic choices to meet increased demand for sustainable fishery production? This presentation is one of two case studies that examine major differences the strategic mix of these approaches for portunid crabs: the blue crab (*Callinectes sapidus*) in Chesapeake Bay USA compared with the swimming crab (*Portunus trituberculatus*) in Zejiang, Jiangshu and Sandong Provinces, China.

The Chesapeake blue crab fishery is complex, with independent fishermen using a diverse array of gear in differing combinations over the seasonal cycle to target separate stages of the migratory life cycle in spatially separate areas. The most important gear has been the crab pot for hard (intermolt) crabs during the warm season from April to November. However, trotlines have been locally important in catching intermolt crabs in tributaries of the upper estuary during summer; and a dredge fishery operated in the mainstem of the lower bay during winter. A small but lucrative output of soft (postmolt) crabs (2% of the weight; 11% of the value) are produced in summer by collecting premolt crabs from the wild and placing them in simple artisanal aquaculture facilities for short periods until molting. The fishery includes both male and female crabs, with males dominating the summer catch in the upper estuary, and females comprising 80% of the catch in the lower estuary.

Historically, the blue crab has supported a productive and valuable fishery. Total blue crab landings increased markedly during 1940 to 1990 from 45 to nearly 100 thousand metric tons per year, with peak values at US$175 million in the late 1990s.

In early decades, 50-60% of the catch was derived from a single large estuary, the Chesapeake Bay; although the contribution from other regions increased in the 1980s. However, from 1991 to 2001 the Chesapeake stock declined markedly: fishery-independent surveys showed the spawning stock declined by 84%, and the total stock dropped by 70% to record low levels that were sustained through 2008. The cause of the rapid decline in the 1990s is not known, but stock assessment showed that the catch per unit effort dropped markedly and that the stock was overfished in 9 out of 11 years from 1998 to 2008.

In response to the marked decline in the Chesapeake stock, two separate approaches developed. First, fishery scientists and managers formed a blue crab advisory commission across management jurisdictions to develop improved management. Using an annual system-wide fishery-independent survey, the group repeatedly up-dated and improved the stock assessment. Attempts to recover the depressed stock resulted in fishery managers imposing numerous frequent changes in fishing regulations; however these changes neither reduced fishing pressure effectively nor increased the stock. One major regulatory change resulted in a greatly expanded sanctuary in the lower estuary that prohibited fishing on the spawning stock during the summer reproductive season; but since fishing of mature females was allowed to proceed in the winter, the spawning stock remained at record low levels through 2007.

In a second approach, the multi-institutional Blue Crab Advanced Research Consortium (BCARC) was formed in 2002 to test the feasibility of using hatchery-reared juveniles to replenish the spawning stock of mature females. BCARC emphasized integration of research on basic biology, hatchery technology, and experimental field releases of tagged juveniles for responsible stock enhancement. Over 8 years of funding totaling US$15million, BCARC significantly increased knowledge of basic physiology and ecology of blue crabs, and successfully developed hatchery technologies to complete the life cycle and produce cohorts of 20 mm juveniles for field experiments. From 2002-2010 we tagged and released 57 cohorts of 2,000-25,000 tagged hatchery-reared juveniles (378,000 crabs total) into nursery habitats of upper Chesapeake Bay plus nearly 150,000 juveniles in the lower bay. Releases resulted in averages of ~300% enhancement, ~15% survival, and production of ~300 adults ha^{-1}; but these averages varied significantly among sites and years, allowing development of optimal release strategies.

By 2008, the fishery was declared in a state of emergency. Traditional fishery management approaches over 15 years had failed to restore the depressed stock. BCARC's research demonstrated successful enhancement at small scale, and clearly showed that the stock was recruitment limited; but funding sources refused to commit additional support to scale up the enhancement approach. In a dramatic shift in management approach, fishing pressure on mature female crabs was greatly reduced by prohibiting fishing on the spawning stock in winter as well as summer. A major increase in juvenile recruitment occurred in 2009, which is now translating into significant recovery of the stock in 2010.

In summary, the BCARC researchers and the fishery managers took separate approaches that were not well coordinated. Each approach had major successes: (A) 8 years of research on stock enhancement provided an excellent example of integrating hatchery and field testing for successful enhancement strategy; (B) a major change in fishery management to reduced fishing pressure on females resulted in a recovery of the stock. However, research on aquaculture, stock enhancement, and fishery management is severely underfunded in the USA. In the blue crab case, the stock enhancement researchers and fishery managers did not cooperate enough, and have now lost the combined synergy to deal with future problems, as well as the momentum to build a stronger base of funding. Key recommendations resulting from this experience include: (1) the need for appropriate mutually agreed metrics of stock enhancement and for stock assessment; (2) the need for early incorporation of economic models into fishery management for regulatory, aquaculture and enhancement approaches; and (3) the need for much increased funding for all three approaches, commensurate with the value of the fishery.

Keynote: Rearing and genetic effects on fitness of artificially-produced animals in the wild: empirical evaluation of large-scale fishery stock enhancement programs

Shuichi Kitada*, Katsuyuki Hamasaki, Kaori Nakajima, Yasuyuki Miyakoshi and Hirohisa Kishino Tokyo University of Marine Science and Technology 4-5-7 Konan, Minato, 108-8477 Tokyo Japan kitada@kaiyodai.ac.jp

In conservation and population management programs, a release of artificially-produced animals is one of the most popular tools. Produced animals released into the natural environment (hereafter "in the wild") interact with wild ones depending on the carrying capacity, and therefore should be compatible with wild ones in successful release programs. Since the late 1980s, there has been growing concern about the ecological and genetic effects of hatchery-reared fish on wild populations. One major source of concern is the replacement of wild fish by hatchery fish. Another concern is the deleterious genetic effects of hatchery fish on wild populations. Anomalous genotypic and phenotypic traits have been observed in hatchery populations since the early 1980s. Significant losses of genetic variation or changes in genotypic frequencies in hatchery populations have been reported for several species. There has been a general increase in awareness of the loss of genetic variation in hatchery populations.

The essential concern is whether the loss of genetic variation causes loss of fitness of hatchery and wild populations. Reisenbichler and McIntyre (1977) first found that the survival of hatchery-produced steelhead *Oncorhynchus mykiss* was lower than that of wild fish in natural streams. Recently, Araki *et al*. (2007a, 2007b), using microsatellite parentage assignments, discovered a considerable reduction in the reproductive success (RS) of hatchery-reared steelhead (F1 fish) when they bred in the wild. Araki *et al*. (2009) also found a carryover effect with an even lower RS in hatchery descendants (F2 fish born in the wild). The lower RS of hatchery fish could result in a reduction in reproductive potential of stocked populations when released fish significantly contribute to the population. However, the mechanisms causing the reduction in RS of steelhead are unknown, and it is not clear to what extent these results extrapolate to other species (Araki *et al.* 2009).
To address this issue, we investigated the causes of the lower RS of hatchery-reared steelhead, and whether the reduction in RS could be generalized to other species. We first tried to extend our understanding of the results of Araki *et al.* (2007a, 2007b, 2009). We then explored the statistical properties of the relative reproductive success (RRS) estimator on the basis of empirical RRS estimates of the steelhead. From this analysis, we hypothesize that rearing in a hatchery over one year affected the reproductive behavior of hatchery-reared steelhead, which resulted in the low RRS. We then examined whether the fitness reduction of hatchery-reared animals occurred in other species using three different types of large-scale release programs from Japan; the chum salmon *Oncorhynchus keta* (conducted over 100 years) and Japanese scallop *Mizuhopecten yessoensis* (~40 years) in Hokkaido, and red sea bream *Pagrus major* in Kagoshima Bay (KB) (~35 years), in which the impact of released fish to the commercial landings was significant and genetic monitoring was conducted.
The number of chum salmon returning and the catch of scallop have increased above historical levels with the increased number of individuals released (Fig. 1A, B). The commercial catch of released red sea bream in KB also increased after the start of the program, but has continued to decrease since early 1990, along with the decreased number of released fish. On the other hand, the wild catch has generally remained

above the catch level at the commencement of release (Fig. 1C).
Most of the annual catch of chum salmon has been created from hatchery fish. Chum salmon returning to spawn are used for artificial propagation every year. Therefore, the case of chum salmon examines the effect of 3–4 months rearing on smolt-to-adult survival of hatchery fish (C[C×C], see Araki et al. 2007a). Catches of Japanese scallop consist of released individuals and wild descendants reproduced from released spat. Naturally-born scallop larvae are collected and bred in net cages for one year in the wild before release. The case of scallop examines the rearing effect on survival and the RS of released spat (W[W×W]) in the wild. The red sea bream program in KB has used nonlocal parents and their progeny for multiple generations kept in concrete tanks. The contribution of hatchery fish to commercial landings in inner KB (IKB) was high at 41.2 ± 26.8% during 1989 and 2004. The time for rearing before release is about 100 days, 50 days in concrete tanks and 50 days in net cages. The case of red sea bream examines the effects of both juvenile rearing and domestication selection of breeders during several generations on survival and RS of hatchery fish (C[C×C]) in the wild.

The increased return rate and the fishery production of chum salmon demonstrated no decline in smolt-to-adult survival in hatchery-reared fish. High survival rates and increased fisheries production of scallop also showed no reduction in survival and RS of released spat. In contrast, the recapture rate for one-year-old red sea bream decreased consistently, suggesting a decline in the survival rate of hatchery fish born from broodstock used to rear multiple generations. The result suggests that hatchery-reared red sea bream were affected by domestication selection of breeders and weaker fish were removed by natural selection in the wild. Nevertheless, the wild catch of red sea bream has generally remained above the catch level at the commencement of release, with a high genetic mixing proportion of hatchery fish in IKB (39.0% ± 73.8%). These results suggest that the juvenile rearing effect and domestication selection of breeders on survival and RS were cancelled by natural selection. A longer rearing duration in a hatchery decreases the effect of natural selection in early life stages, in which natural mortality is very high in aquatic animals. Empirical data teaches us that hatchery-reared animals with relaxed natural selection in captivity are again exposed to natural selection in species-specific survival and reproductive processes with wild animals.

Keynote: "Perspectives on 'A Responsible Approach to Marine Stock Enhancement: An Update': better integration with fishery assessment, management, and stakeholder involvement"

Kenneth M. Leber[1], Kai Lorenzen[2] and H. Lee Blankenship[3]
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Marine fisheries enhancement is a set of management approaches involving the release of cultured organisms to enhance or restore fisheries. Such practices, including sea ranching, stock enhancement, and restocking, are widespread, of variable success, and often controversial. In principle, enhancements can help increase yield in fisheries, aid in conservation and rebuilding of depleted, threatened and endangered

populations, provide partial mitigation for habitat loss and ecosystem effects of fishing, and help create new fisheries in restored habitats. Enhancements may afford economic and social benefits and incentives for active management and better governance. However, many enhancements have failed to deliver significant increases in yield or economic benefits or have contributed to management failure by encouraging or compensating for counterproductive changes in fishing practices or for habitat degradation. While some enhancement initiatives have been successful, only a few such ‘success stories’ have been documented in the scientific literature. It is constructive to ask why haven’t enhancements made a greater contribution to fisheries. We believe there are several contributing factors. Success in fisheries management is measured against a broad set of criteria – biological, economic, social, and institutional attributes. Enhancements score well on some criteria, but only under certain situations delineated by ecological, economic and social conditions, by institutional arrangements that are well adapted to those conditions, and by adding value to other management measures. Thus, they need to be assessed, if not driven, from a fisheries management perspective, rather than the aquaculture production perspective that has been traditionally dominant.

Over the past two decades there has been a rapid increase in research and development of the science and tactics needed for enhancement to be effective. This is evidenced by the significant increase in peer-reviewed publications on restocking, stock enhancement and sea ranching research. Several key papers have had a strong influence on developing the science needed to realize effective enhancements. A set of principles aimed at promoting responsible development of restocking, stock enhancement, and sea ranching has gained widespread acceptance as a ‘Responsible Approach’. Fisheries science and management, in general, and many aspects of fisheries enhancement have developed rapidly since the Responsible Approach was first formulated. We present an overview of our update to the Responsible Approach, which was written in light of these developments. The updated approach emphasizes the need for taking a broad and integrated view of the role of enhancements within fisheries management systems; using a stakeholder participatory and scientifically informed, accountable planning process; and assessing the potential contribution of enhancement and alternative or additional measures to fisheries management goals early on in the development or reform process. Progress in fisheries assessment methods applicable to enhancements and in fisheries governance provides the means for practical implementation of the updated approach.

KEY WORDS Stock enhancement, sea ranching, restocking, responsible approach, planning, fisheries assessment, population dynamic

Keynote: "Quantitative approaches to evaluating the contribution of release programs to fisheries management goals"

Professor Kai Lorenzen (Florida University, United States)
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Quantitative assessment of the contribution a release program can make to fisheries management goals, including synergies and tradeoffs with fishing regulations and habitat management, is a key requirement if enhancements are to be effective and sustainable. Population dynamics theory and quantitative assessment methods for enhanced fisheries have developed rapidly over the past decade. I provide a critical review of recent developments in the areas of population dynamics theory, the dynamics of alternative enhancement systems, assessment approaches, monitoring and experimental design, and reference points and management control rules. I close by outlining a set of best practice guidelines for quantitative assessments and priorities for further research.

Population dynamics models commonly used in fisheries assessment have been extended in various ways to allow evaluation of release programs. This includes 'unpacking' of the stock-recruitment relationship to describe dynamics in the pre-recruit stage explicitly; quantifying compensatory density-dependent processes in the recruited phase of the life cycle; accounting for differences in fitness between hatchery-released and wild fish; and explicitly modelling spatial dynamics. In several areas, such as the consideration of size-dependence in lifetime mortality schedules, models originally developed for enhanced fisheries have become widely used in the assessment of wild stocks.

Release programs can be used in different situations and for different purposes, which in turn give rise to very different approaches to population assessment and management. Five main types of marine fisheries enhancement systems may be distinguished, in a sequence ranging from the most production-oriented to the most conservation-oriented type: sea ranching, stock enhancement, restocking, supplementation and re-introduction. Ranching systems operate for species that do not recruit naturally and may be managed to maximize somatic production (commercial fisheries) or the abundance of catchable-sized fish (recreational fisheries), often manipulating population in ways that could not be achieved in naturally recruiting populations. Because direct genetic interactions with wild stocks are absent, post-release fitness of cultured fish is primarily an economic rather than a conservation issue. Stock enhancement involves the continued release of hatchery fish into a self-recruiting wild population, with the aim of sustaining and improving fisheries in the face of intensive exploitation and/or habitat degradation. Enhancement through release of recruits or advanced juveniles may increase total yield and stock abundance, but is likely to reduce abundance of the naturally recruited stock component through compensatory responses or overfishing. Stocking and harvesting rates in such fisheries are strongly constrained by stock conservation considerations. Impacts on the wild population component can be reduced by separating the cultured/stocked and wild population components as far as possible. Re-stocking involves time-limited releases of hatchery fish, aimed at rebuilding depleted

populations more quickly than would be achieved by natural recovery. In re-stocking, release number must be substantial relative to the abundance of the remaining wild stock if rebuilding is to be significantly accelerated. Restocking cannot substitute for effort limitation, and is advantageous as an auxiliary measure only if the population has been reduced to a very low proportion of its unexploited biomass.

Quantitative assessments of fishery management contributions should be carried out at all stages of development of a release program, from early planning to full-scale operation. Model components and parameters may be estimated from three principal sources: (1) quantitative assessments of the wild stock, (2) release experiments with marked fish, and (3) comparative empirical studies and meta-analyses. Assessment of fisheries enhanced through hatchery releases requires more extensive monitoring than that of fisheries sustained by natural recruitment alone. In particular, wild and hatchery-origin fish must be distinguished and the fitness of hatchery fish and their hybrids with wild fish evaluated. Wherever possible, enhancements should be designed as experiments with spatial and temporal controls.

Reference points define targets or limits of stock status in fisheries management. Where release programs are carried out at operational scales, reference points should be defined for the combined stock and for its wild component. Reference points and management control rules for enhanced fisheries have received insufficient attention in research and fisheries governance.

Program of Oral Presentations

Thursday 21st April 2011			
No.	**Time**	**Presenter**	**Title**
1&2	1400	Xing-wu Zhao	**Overview:** Strengthen aquatic research protection, enhance ecological culture construction and fisheries sustainable development – China's aquatic resource protection, actions and achievements
THEME A: The role of releases of cultured animals in fisheries management and ecosystem restoration: integrative evaluation **Conveners: Dr Ann-Lisbeth Agnalt, Dr Jin Xianshi**			
3	1440	*Xianshi Jin*	Successful practices in the restocking of depleted fisheries in the Bohai Sea
4	1500	Guan Changtao	Research Progress on the construction of marine ranching along the coast of Shandong Province
5	1520	Zhongxin Wu	Evaluating ecosystem structure and predicting the ecological carrying capacity for *Stichopus japonicus* and *Haliotis discus hannai* of Liado artificial reef zone in Shandong Province
6	1540	T Sugaya	Large scale assessments of the effect of Kuruma prawn stocking using DNA markers in Japan
	1600		Afternoon tea, Exhibition and Trade and Poster viewing
7&8	1620	Professor Kai Lorenzen	**Keynote:** Quantitative approaches to evaluating the contribution of release programs to Fisheries management goals
THEME B: Modelling and assessing the effectiveness of releases for fisheries management and conservation **Convenors: Dr Matthew Taylor, Dr Zhuang Ping**			
9	1700	Chen Pimao	Effect assessment of fishery stock enhancement in Guangdong coastal waters
10	1720	G Burnell	A community based scallop restoration project in Co. Kerry, Ireland

Friday 22nd April 2011			
No.	**Time**	**Presenter**	**Title**
11	0840	Jeremy Prince	Cost Benefit Analysis of alternative Techniques for Rehabilitating Abalone Reefs Depleted by Abalone Viral Ganglioneuritis
12, 13 & 14	0900	Anson H. Hines Cheng Yongxu	**Keynote:** Strategic mixing of fisheries management, aquaculture and stock enhancement: Case of the Chesapeake Blue Crab **Keynote:** The biology, culture and enhancement of swimmer crabs *Portunus Trituberculatis* in China
	1000		Morning tea, Exhibition and Trade and Poster viewing
15	1020	Anthony M. Hart	Stock enhancement in greenlip abalone: Population and ecological effects
16	1040	Jennifer Chaplin	Biological performance and genetics of restocked and wild Black Bream in an Australian Estuary
THEME C: Governance and the socio-economics of releases **Convenors: Prof. Kai Lorenzen, Dr Devin Bartley, Dr Lu Weiqun**			
17	1100	Marie Antonette Paña	Governance mechanisms and socio-economic considerations for communal sandfish Sea Ranching in the Philippines
18	1120	Marcel LeBreton	Return on investment for a lobster (*Homarus Americanus*) enhancement project in Atlantic Canada
19	1140	Nerissa Salayo	Regulating catch size to support Abalone stock enhancement initiatives: Experiences in Sagay City, Philippines
20	1200	Qing-yin Wang	Ecosystem-based Sea Ranching in Zhangzidao in Northern Yellow Sea
21	1220	Neil Loneragan	Stock enhancement and restocking in Australia and opportunities for Finfish, particularly in Western Australia
	1240		**Lunch, Exhibition and Trade and Poster viewing**
22	1400	Devin Bartley	Ecolabelling and enhanced fisheries: International guidelines
23	1420	Bernard Walrut	Regulation of Sea Ranching and Enhancement
24	1440	Ruth Gamboa	The long and winding road in Sea Ranching
THEME E: Interactions between wild and released animals and their ecological and genetic implications **Convenors: Mr Lee Blankenship, Prof. CHANG, Yaqing**			
25	1500	Bridget Green	Overlap of some home ranges of resident and introduced southern Rock Lobster after translocation
26	1520	Knut Jørstad	Genetic tagging of farmed Atlantic Cod (*Gadus Morhua L.*) and detection of escapement from a commercial cod farm
	1540		Afternoon tea, Exhibition and Trade and Poster viewing

Friday 22nd April 2011 continued			
No.	**Time**	**Presenter**	**Title**
27	1600	Blanco Gonzalez	Genetic interactions between wild and hatchery Red Sea Bream confirmed by microsatellite genetic markers
28	1620	John Russell	Ecological and genetic impacts of Barramundi (*Lates Calcarifer*) stocking in Northern Australia
29	1640		Summary
30&31	1700	Shuichi Kitada	**Keynote:** Rearing and the genetic effects on fitness of artificially-produced animals in the wild: Empirical evaluation of large-scale fishery stock enhancement programs
THEME D: Developing optimal release strategies **Convenors:** Dr Ken Leber, Prof. ZHANG Xiumei			
32	1740	Ann-Lisbeth Agnalt	Carrying capacity in juvenile stages of European Lobster (*Homarus Gammarus*); Essential knowledge for restocking/sea ranching
33	1800	Junemie Hazel Lebata-Ramos	Establishing release strategies for stock enhancement of hatchery-reared Abalone Haliotis Asinia

Saturday 23rd April 2011			
No.	**Time**	**Presenter**	**Title**
34	0840	Roger G. Dolorosa	*Trochus niloticus* translocation: Prospects in enhancing depleted Philippine reefs
35	0900	Ellen Sofie Grefsrud	Impact of fenced scallop (*Pecten Maximus*) sea-ranching on Benthic Fauna
36&37	0920	Kenneth Leber	**Keynote:** Perspectives on a 'Responsible approach to marine stock enhancement: An update': Better integration with fishery assessment, management and stakeholder involvement
	1000		Morning tea, Exhibition and Trade and Poster viewing
38	1020	Eric Johnson	Optimising release strategies for blue crabs in Chesapeake Bay
39	1040	James Smith	Finding the right starting points in stocked fisheries by modelling the right end points: Expressing the carrying capacity as a function and a dynamic equilibrium
40	1100	Hongjian Lv	The use of plastic oval tags for mark-recapture studies of juvenile Japanese Flounder *Paralichthys olivaceus* on the North-east coast of Shandong Province, China
41	1120	Michelle Walsh	Obama's floundering: Post-release abilities, characteristics and assessment of cage conditioned Japanese Flounder, *Paralichthys Olivaceus*

Saturday 23rd April 2011 continued			
No.	**Time**	**Presenter**	**Title**
42	1140	Elizabeth Fairchild	Implementing a new stocking program in unchartered waters: Developing optimal release strategies for winter flounder in Massachusetts and New York, USA
43	1200	Jonathan Lee	Site fidelity and movement of hatchery-reared lingcod released into Puget Sound, Washington, USA
44	1220	Yuuki Kawabata	Shelter acclimstion decreases the post-release predatin mortality of hathery-reared Black-spot Tuskfish .*Choerodon Schoenleinii*
	1240		**Lunch, Exhibition and Trade and Poster viewing**
45	1400	Byung Sun Chin	Determining optimal release habitat for black rockfish: Examining growth rate, feeding condition and recapture rate
THEME F: Enhanced knowledge on populations and ecosystems from releases of cultured animals **Convenors: Prof. Neil Loneragan, A. Prof. TANG, Jianye**			
46	1420	Marie Antonette Juinio-Meñez	Growth survival and reproduction of sandfish *Holothuria Scabra* released in a pilot sea ranch in the Philippines
47	1440	Katherine Doyle	Does stocking Australian native predatory fish provide a control option of invasive European Carp (*Cyprinus Carpio*)
48	1500	Raquel Moura Coimbra	The first catfish, *Pseudoplatystoma corruscans*, restocking program in the Sao Francisco River Basin: Analysing the representativeness of it's founder stock
49	1520	Weimin Quan	Early development of sessile and epifaunal community on a created intertidal oyster *Crassostrea Ariakensis* Reef in the Yangtze River Estuary, China
	1540		Afternoon tea, Exhibition and Trade and Poster viewing
THEME G: Adapting to change: climate, habitat and socio-economics **Convernors: Prof. Masahide Kaeriyma, Dr Minling Pan, Prof. YANG, Ningsheng**			
50	1600	Masahide Kaeriyama	Sustainable fisheries management of Pacific Salmon under the warming climate
51	1620	Kelly Davidson	Measuring the effect of socioeconomic factors on consumer preferences for seafood – A case study in Hawaii
52	1640	Yasuyuki Miyakoshi	Current hatchery programs and future stock management of Chum Salmon in Hokkaido, Northern Japan
53	1700	Sarah Jennings	Marine Stock Enhancements under a changing climate: Implications for the responsible enhancement approach
	1720		Summary
	1730	**Happy Hour and Closing Ceremony**	

ABSTRACTS for Oral presentations
at the
4th International Symposium on Stock Enhancement and Sea Ranching.

OVERVIEW OF CURRENT AND FUTURE DIRECTIONS IN CHINA

1&2. STRENGTHEN AQUATIC RESOURCE PROTECTION, ENHANCE ECOLOGICAL CULTURE CONSTRUCTION AND FISHERIES SUSTAINABLE DEVELOPMENT - CHINA'S AQUATIC RESOURCE PROTECTION, ACTIONS AND ACHIEVEMENTS

标题：加强水生生物资源养护 走生态文明建设和渔业可持续发展之路

副标题：——中国水生生物资源养护行动与成效

作者：农业部渔业局局长 赵兴武

概要：文章介绍了中国水生生物资源养护的政策，主要开展的增殖放流、建立水产种质资源保护区、实施禁渔休渔管理、濒危水生野生动物保护和水域生态保护等方面养护行动，总结了在经济、生态和社会方面取得的成效，对未来水生生物资源养护的发展趋势作了展望。

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In this report, the Chinese policies on aquatic resource protection will be discussed, along with major stock enhancement release projects, protected areas for commercially important biological resources, mandatory moratorium periods, protection of endangered wild aquatic animals and aquatic ecosystem protection etc.. The economic, ecological and social achievements of aquatic resource protection will be summarized, and future trends and developments will be discussed.

THEME A: The role of releases of cultured animals in fisheries management and ecosystem restoration: integrative evaluation

3. SUCCESSFUL PRACTICES IN THE RESTOCKING OF DEPLETED FISHERIES SPECIES IN THE BOHAI SEA

Xianshi JIN[1], *Jun WANG*[1], *Shengrao*[2], *Zhenliang ZHAO*[3], *Jing DONG*[4]
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The biomass of many marine species declined and the commercially high-valued, large-sized species were depleted or replaced by low-valued, small-sized species in the Chinese coastal waters. Restocking of depleted fisheries stocks are urgent. Except the management, many species have been released the sea waters to rebuild the stocks. This paper firstly reviews the progress of stock enhancement in the China, and then focus on the Fleshy prawn (*Fenneropenaeus chinesensis*) enhancement in the Bohai Sea. This species was the highest value species and the catch decreased from more than 40000 t in 1979 to several hundred ton before the large-scale enhancement. In 2009 and 2010, two billion and three billion of fleshy prawn was released into the Bohai Sea, about 2 377t and 5 270 t were caught, valued 315million Yuan and 754 million Yuan, respectively. The enhancement of blue crab (*Portunus trituberculatus*) and jellyfish (*Rhopilema esculenta*) also showed encouraging results. The current successful practices indicate that stock enhancement is able to increase the stock size and recapture as well as the income of fishermen. Large scale restocking of depleted species needs more input

by both manpower and financing. The species interaction and impact on the ecosystem should be considered.

4. RESEARCH PROGRESS ON THE CONSTRUCTION OF MARINE RANCHING ALONG THE COAST OF SHANDONG PROVINCE

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By means of deploying artificial reefs, constructing algal reef and seaweed beds, stock enhancement, acoustic domestication and ecologic management, construction of marine ranching is able to promote marine productivity, increase resource density, control behavior of fish, produce at scale, realize sustainable exploitation and utilization of fishery resource. It embodies the feature of modern fishery and low-carbon circular economy, which is an important direction of future fishery. Setting up artificial reefs is an important step for the construction of marine ranching. Since "The Tenth Five-year Plan of China", offshore environment improvement, stock enhancement and mariculture development have been given very high degree of importance along the coast of Shandong province. Studies and tests on artificial reefs and marine ranching, including effect investigation of artificial reefs set up in Jiaonan coastal areas in 1980's, hydrodynamic characteristics experiment of artificial reef, study on material and configuration of artificial reef models, algae transplantation and seaweed beds construction, stock enhancement and releasing etc., have been carried out in recent years. Furthermore, the Restoration Plan of Fishery Resources of Shandong Province has been implemented since the year of 2005, which greatly boosted the construction of artificial reefs and marine ranching along the coast of Shandong. By June of 2010, the number of artificial reef construction projects which were supported by government financial capital has been up to 21. Total investment is over 77 million USD. 100 artificial reef districts, with total area about 33,350,000 square meters have been set up. The total volume of artificial reefs has been up to 2,266,000 hollow cubic meters, among which, 1,537,900 m^3 are stone reefs, 6,469,000 m^3 are made of concrete and the rest comes from 334 retired ships. With four large scale artificial reef zones being established, the construction of marine ranching along the coast of Shandong province has been in certain scale and the economic, social and ecological effects are obvious.

KEY WORDS Marine ranching; Artificial reef; Shandong province

5. EVALUATING ECOSYSTEM STRUCTURE AND PREDICTING THE ECOLOGICAL CARRYING CAPACITY FOR *Stichopus japonicus* AND *Haliotis discus hannai* OF LIDAO ARTIFICAL REEF ZONE IN SHANDONG PROVINCE

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Based on the environmental and biological data obtained from monthly surveys in Lidao artifical reef zone during 2009, a balanced trophic model of Lidao artifical reef ecosystem was constructed by using the Ecopath with Ecosim software package. The model consisted of 19 functional groups which covered the main trophic flow in Lidao artifical reef ecosystem. Trophic flow and ecological carrying capacity of the artifical reef system were analyzed and predicted. The results showed that the trophic level of the function groups varied from 1.0~3.921. The geometric mean of the trophic transfer efficiencies was 9.9%, with 10.3% from detritus and 9.7% from primary producers within the system. In the course of the trophic flow, the proportion of total flow originating from detritus was 39％, and from primary producer was 61％. Four

ecosystem attributes including TPP/TR(total primary production/ total respiration), CI(connectivity index), FCI(Finn's cycling index) and MPL(mean path length) were 2.688, 0.321, 2.20 and 2.357 respectively, indicating that the system is approaching the mature stage according to Odum's theory. The ecological enviroment and the output of fisheries in artifcial reef zone will be gradually steady. Moreover, we predicted the ecological carrying capacity for sea cucumber(*Stichopus japonicus*) and abalone(*Haliotis discus hannai*), which are the main enhancemental species in the system. The ecological carrying capacity was defined as the level of enhancement that could be introduced without significantly changing the major trophic fluxes or structure of the food web. The ecological carrying capacities for sea cucumber and abalone were found to be 309 t km^{-2} $year^{-1}$ and 198.86 t km^{-2} $year^{-1}$ in Lidao artifical reef zone, respectively.

6. LARGE-SCALE ASSESSMENTS OF THE EFFECT OF KURUMA PRAWN STOCKING USING DNA MARKERS IN JAPAN

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Kuruma prawn *Marsupenaeus japonicus* is a marine shrimp widely distributed from temperate to tropical zones of the world. While this prawn is one of the most famous fishery animals in Japan, the fishery yield has rapidly declined during late 1960's. From such a situation, stock enhancement programs with annual release of approximately 150 million hatchery-reared individuals have been promoted mainly in southern Japan for about 30 years. However, the stocking effects of such the mass prawn release were not examined directly, although the experimental releases of tagged individuals was performed many times to presume the stocking effects.

In this study, we have performed large-scale assessments of the stocking effects of kuruma prawn using a mitochondria DNA (mtDNA) and three microsatellites DNA (msDNA) markers in three coastal areas (Saiki Bay, Suo-nada and Ariake Sea) where several millions of prawns have been released annually. During 2006 to 2010, we collected 1591 dams and 4261 wild-caught kuruma prawns from hatcheries and fish markets, respectively. Pedigree analyses showed that 4 to 12 % of the wild-caught prawns were released seeds, and the comparisons of monthly mix rates of the seeds between the fish markets showed relatively rapid dispersions of the seeds. Besides, the genetic impact of prawn stocking was examined based on the relatedness analysis of continuously sampled wild individuals in Saiki Bay. Although mean relatedness in the samples estimated by three MS-DNA markers were almost zero, the relatedness among the individuals sharing common haplotypes in nucleotides sequences analysis of mtDNA control region were from 0.126 to 0.458, suggesting the dominance of the hatchery-reared juveniles around the stocking area.

KEYNOTE: Evaluating releases

7&8. QUANTITATIVE APPROACHES TO EVALUATING THE CONTRIBUTION OF RELEASE PROGRAMS TO FISHERIES MANAGEMENT GOALS

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Quantitative assessment of the contribution a release program can make to fisheries management goals, including synergies and tradeoffs with fishing regulations and habitat management, is a key requirement if enhancements are to be effective and sustainable. Population dynamics theory and quantitative assessment methods for enhanced fisheries have developed rapidly over the past decade. I provide a critical review of recent developments in the areas of population dynamics theory, the dynamics of alternative enhancement systems, assessment approaches, monitoring and experimental design, and reference points and management control rules. I close by outlining a set of best practice guidelines for quantitative assessments and priorities for further research.

Population dynamics models commonly used in fisheries assessment have been extended in various ways to allow evaluation of release programs. This includes 'unpacking' of the stock-recruitment relationship to describe dynamics in the pre-recruit stage explicitly; quantifying compensatory density-dependent processes in the recruited phase of the life cycle; accounting for differences in fitness between hatchery-released and wild fish; and explicitly modelling spatial dynamics. In several areas, such as the consideration of size-dependence in lifetime mortality schedules, models originally developed for enhanced fisheries have become widely used in the assessment of wild stocks.

Release programs can be used in different situations and for different purposes, which in turn give rise to very different approaches to population assessment and management. Five main types of marine fisheries enhancement systems may be distinguished, in a sequence ranging from the most production-oriented to the most conservation-oriented type: sea ranching, stock enhancement, restocking, supplementation and re-introduction. Ranching systems operate for species that do not recruit naturally and may be managed to maximize somatic production (commercial fisheries) or the abundance of catchable-sized fish (recreational fisheries), often manipulating population in ways that could not be achieved in naturally recruiting populations. Because direct genetic interactions with wild stocks are absent, post-release fitness of cultured fish is primarily an economic rather than a conservation issue. Stock enhancement involves the continued release of hatchery fish into a self-recruiting wild population, with the aim of sustaining and improving fisheries in the face of intensive exploitation and/or habitat degradation. Enhancement through release of recruits or advanced juveniles may increase total yield and stock abundance, but is likely to reduce abundance of the naturally recruited stock component through compensatory responses or overfishing. Stocking and harvesting rates in such fisheries are strongly constrained by stock conservation considerations. Impacts on the wild population component can be reduced by separating the cultured/stocked and wild population components as far as possible. Re-stocking involves time-limited releases of hatchery fish, aimed at rebuilding depleted populations more quickly than would be achieved by natural recovery. In re-stocking, release number must be substantial relative to the abundance of the remaining wild stock if rebuilding is to be significantly accelerated. Restocking cannot substitute for effort limitation, and is advantageous as an auxiliary measure only if the population has been reduced to a very low proportion of its unexploited biomass.

Quantitative assessments of fishery management contributions should be carried out at all stages of development of a release program, from early planning to full-scale operation. Model components and parameters may be estimated from three principal sources: (1) quantitative assessments of the wild stock, (2) release experiments with marked fish, and (3) comparative empirical studies and meta-analyses. Assessment of fisheries enhanced through hatchery releases requires more extensive monitoring than that of fisheries sustained by natural recruitment alone. In particular, wild and hatchery-origin fish must be distinguished and the fitness of hatchery fish and their hybrids with wild fish evaluated. Wherever possible, enhancements should be designed as experiments with spatial and temporal controls.

Reference points define targets or limits of stock status in fisheries management. Where release programs are carried out at operational scales, reference points should be defined for the combined stock and for its wild component. Reference points and management control rules for enhanced fisheries have received insufficient attention in research and fisheries governance.

THEME B: Modelling and assessing the effectiveness of releases for fisheries management and conservation

9. EFFECT ASSESSMENT OF FISHERY STOCK ENHANCEMENT IN GUANGDONG COASTAL WATERS

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14.473 million fish fry including *Lutianus sanguineus*, *Pagrosomus major*, *Mylio macrocephalus* and *Sparus latus* and 96.32 million shrimp larvae including *Penaeus monodon*, *P. chinensis*, *P. penicillatus* and *P. merguiensis* were released across 21 locations in the coastal waters of East Guangdong, Pearl River Estuary, West Guangdong and Beibu Gulf in Guangdong Province. Released fish and shrimp were sampled through a combination of market surveys, fishing log-book surveys and fishery independent gill net surveys. The growth and abundance of stocked species were used to assess the effectiveness of fishery enhancement, and estimate enhancement carrying capacity. The combined fishing production, output value and input-output ratio reached 192.64 tons, 19.5851 million RMB and 1:11.19 respectively for the four species of released shrimp during the first two years post-release, and reached 344.94 tons, 41.1918 million RMB and 1:5.68 for the four species of released fish during the first three years post-release. Fisherman gained an income increase of 6800 RMB per year, revealing a significant improvement in economic return. Shrimp and fish surviving to sexual maturity was approximately 1.217 million shrimp (after 2 years) and 228 thousand fish (after 3 years), which could contribute to the spawning stock and help achieve the goals of sustainable development and development of a healthy ecosystem.

Stock enhancement carrying capacity was estimated at 12.20 million, 58.41 million, 6.31 million, 19.15 million, 47.12 million, 18.04 million, 68.20 million and 34.92 million for *Lutianus sanguineus*, *Pagrosomus major*, *Mylio macrocephalus*, *Sparus latus, Penaeus monodon*, *Penaeus chinensis*, *Penaeus penicillatus* and *Penaeus merguiensis* respectively. Actual enhancement quantities were about 1/7 and 1/2 of the fish and shrimp enhancement carrying capacity. Based on the result the quantity of enhancement should be increased.

Enhancement in Guangdong Coastal water in 2010 occurred after a Fishing-Prohibited Period of the South China Sea, to increase the economic benefit and ecological results of enhancement. Enhancement and recapture strategies should be adjusted to align with the optimal values determined from this survey.

10. A COMMUNITY BASED SCALLOP RESTORATION PROJECT IN CO. KERRY, IRELAND

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Valentia Harbour, County Kerry, has been the site of a valuable King Scallop (*Pecten maximus*) fishery since the nineteenth century. Increased mechanisation of the fishery since the 1930's resulted in a higher catch per unit effort for this fishery with vessels capable of catching "150 dozen fish per day". Such high catch rates were unsustainable and ultimately led to the collapse of the fishery. This was reflected in consistently poor catch statistics in the 1970's and 1980's. Attempts to regenerate this fishery since 1991 have included a variety of measures such as restocking programmes, technical conservation measures, scallop stock assessments and the development of hydrodynamic and transport models to identify patterns of larval dispersal within the harbour and surrounding locations. However, each strategy, when implemented as a sole regeneration measure, has been ineffective. It has become increasingly clear that several, simultaneously implemented approaches may be necessary to regenerate this fishery. The current "ecosystem approach", by using local broodstock and "going with the flow" of the bay, will try to build a sustainable fishery based upon the carrying capacity of the harbour and in sympathy with other local stakeholders. It involves a collaborative research project between the Valentia Harbour Fishery Society, three national research centres; The Daithi O Murchu Marine Research Centre (DOMMRC), The Aquaculture and Fisheries Development Centre, NUI, Galway and Bord Iascaigh Mhara (BIM). The data generated will be used to modify and calibrate a hydrodynamic and transport model. This tool will inform management of the scallop fishery by allowing the cooperative members to quantify the restoration risks and to place the broodstock in a site that optimises larval retention and ultimately improves settlement on artificial collectors.

This project is part supported by the Beaufort Marine Research Award an **Ecosystems Approach to Fisheries Management** with the support of the Marine Institute, funded under the Marine Research Sub-Programme of the National Development Plan 2007–2013.

11. COST BENEFIT ANALYSIS OF ALTERNATIVE TECHNIQUES FOR REHABILITATING ABALONE REEFS DEPLETED BY ABALONE VIRAL GANGLIONEURITIS.

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The newly described herpes-like virus, Abalone Viral Ganglioneuritis (AVG) was first observed in an ocean discharging hatchery in December 2005 at the centre of the western zone abalone fishery in Victoria, Australia. In May 2006 it began a pathological epidemic in the adjacent natural beds of the blacklip abalone (*Haliotis rubra*), moving eastwards through the zone with the prevailing inshore current. Clinical tests suggested

that infection rates as low as a single viral particle produced 100% mortality in 2-3 days. The epidemic was observed to cut large swathes through the natural beds apparently causing total mortality in some parts but leaving other populations of abalone near unaffected and apparently un-infectious. At broader scales mortality rates were estimated at >95 – 45%. Following the epidemic, the Western Abalone Divers Association (WADA) initiated this study of the feasibility and relative merits of alternative methods for rehabilitating the most heavily impacted reefs. The Kilarney Reef in which a mortality rate of 85-95% had been observed and for which a quantitative stock assessment existed was selected as a case study for this cost-benefit analysis. The stock assessment suggested 100-20t of adult biomass had been lost due to the virus.
The local fishery assessment model was adapted to describe both population dynamics and the economics of reseeding, translocation and naturally rebuilding reef in the Western Zone of Victoria, Australia. The literature on abalone reseeding, translocation and natural mortality rates, were used along cost estimates provided by the abalone quota owners, hatcheries and processers to provide agreed 'best' parameter estimates for the model, which was used to analyze the likely costs and benefits of the alternative techniques of rehabilitating the Kilarney Reef code in western Victoria. Comparative economic performances were quantified as the impaired value of the Individual Transferable Quota for the area until the stock recovered to the level of maximum sustainable yield, as it was estimated to be prior to the AVG impact.

The literature shows that, at least, in Japan the augmentation of abalone stocks by reseeding juveniles, and the translocation of adults is technically feasible, although the literature from other parts of the world is more equivocal. It is not possible to determine from the literature whether the difference between the Japanese experience, and that of other countries, is due to lower predator levels in Japan, as claimed by some, or the inherent biases associated with the differing experimental designs employed outside Japan. The assumed mortality parameters for each rehabilitation strategy are critically important to the results of the analysis, as well as being notoriously difficult to estimate. Only in Japan have long term, large scale augmentation programs been attempted and fishery wide returns monitored until the augmented year classes have been fished out, producing truly reliable estimates of survival following reseeding and translocation. Outside Japan studies have been small scale, short-term experiments, so that recapture rates have been depressed by the cryptic nature of juvenile abalone, and movement out of research areas. Consequently the Japanese body of literature was used to substantially determine the range of mortality estimates used. For each of the parameters for which the analysis was found to be sensitive a range of values around the agreed best estimate were analysed. When the cost of capital was accounted for, none of the scenarios involving active intervention produced any cost benefit above that estimated to accrue from allowing an unfished natural recovery. Reseeding and the translocation of adults and were found to be similarly cost-effective. Across the scenarios modelled, translocation was estimated to always at least pay for direct costs, but did not always cover capital costs, while reseeding only covered direct costs if the price of abalone exceeded $40/kg and seed was cheap. In addition to the assumptions used about mortality rates and prices, these results and their general applicability are strongly conditioned by two further assumptions used in this model. Firstly, the standard form of the stock-recruitment relationship (SRR) widely applied in fisheries assessment, and used here, assumes that rates of recruitment per spawning biomass increases as density declines. In contrast, some abalone ecologists believe that abalone productivity declines disproportionately at very low densities (depensation), however, no data on this effect could be found in the literature and its potential effect was not analysed. The existence of a strong depensatory effect could completely negate this analysis. Secondly, the length of time taken by blacklip abalone in Victoria to grow through into the spawning stock is 7-10 years and this determines that both active rehabilitation techniques incur a high compounded cost of capital, which is not incurred in naturally rebuilding scenarios. Generally, it was the compounded cost of capital that mitigated against active rehabilitation being cost effective. Other abalone species grow more rapidly to maturity and if fast enough, the enhanced rate of rebuild might pay for, or profit over, capital costs of active rehabilitation. A final result concerns the timing of intervention. Given the form of the SRR curve used, rapidly rebuilding breeding stock levels immediately after catastrophic depletions, has the best prospect of being profitable. Later interventions, and interventions when stock levels are closer to carrying capacity are less cost-effective. This work appears to be the first time a fully specified quantitative population model has been used to analyse the biological and economic processes underlying the rehabilitation of abalone reefs.

Keynotes: Comprehensive case studies

12&13. STRATEGIC MIXING OF FISHERY MANAGEMENT, AQUACULTURE AND STOCK ENHANCEMENT: CASE OF THE CHESAPEAKE BLUE CRAB.

Anson H. Hines[1], Eric G. Johnson[1], Romuald N. Lipcius[2], Rochelle D. Seitz[2], Oded Zmora[3], Yonathan Zohar[3], David Eggleston[4], and Kenneth Leber[5].

Three main approaches are used in seafood production strategies: fishery management of wild stocks by regulating catch; aquaculture for directly consumable products; and stock enhancement or sea ranching that blends aquaculture with fishery management in open environments. How should these approaches be applied in strategic choices to meet increased demand for sustainable fishery production? This presentation is one of two case studies that examine major differences the strategic mix of these approaches for portunid crabs: the blue crab (*Callinectes sapidus*) in Chesapeake Bay USA compared with the swimming crab (*Portunus trituberculatus*) in Zejiang, Jiangshu and Sandong Provinces, China.

The Chesapeake blue crab fishery is complex, with independent fishermen using a diverse array of gear in differing combinations over the seasonal cycle to target separate stages of the migratory life cycle in spatially separate areas. The most important gear has been the crab pot for hard (intermolt) crabs during the warm season from April to November. However, trotlines have been locally important in catching intermolt crabs in tributaries of the upper estuary during summer; and a dredge fishery operated in the mainstem of the lower bay during winter. A small but lucrative output of soft (postmolt) crabs (2% of the weight; 11% of the value) are produced in summer by collecting premolt crabs from the wild and placing them in simple artisanal aquaculture facilities for short periods until molting. The fishery includes both male and female crabs, with males dominating the summer catch in the upper estuary, and females comprising 80% of the catch in the lower estuary.

Historically, the blue crab has supported a productive and valuable fishery. Total blue crab landings increased markedly during 1940 to 1990 from 45 to nearly 100 thousand metric tons per year, with peak values at US$175 million in the late 1990s. In early decades, 50-60% of the catch was derived from a single large estuary, the Chesapeake Bay; although the contribution from other regions increased in the 1980s. However, from 1991 to 2001 the Chesapeake stock declined markedly: fishery-independent surveys showed the spawning stock declined by 84%, and the total stock dropped by 70% to record low levels that were sustained through 2008. The cause of the rapid decline in the 1990s is not known, but stock assessment showed that the catch per unit effort dropped markedly and that the stock was overfished in 9 out of 11 years from 1998 to 2008.

In response to the marked decline in the Chesapeake stock, two separate approaches developed. First, fishery scientists and managers formed a blue crab advisory commission across management jurisdictions to develop improved management. Using an annual system-wide fishery-independent survey, the group repeatedly up-dated and improved the stock assessment. Attempts to recover the depressed stock resulted in fishery managers imposing numerous frequent changes in fishing regulations; however these changes neither reduced fishing pressure effectively nor increased the stock. One major regulatory change resulted in a greatly expanded sanctuary in the lower estuary that prohibited fishing on the spawning stock during the summer reproductive season; but since fishing of mature females was allowed to proceed in the winter, the spawning stock remained at record low levels through 2007.

In a second approach, the multi-institutional Blue Crab Advanced Research Consortium (BCARC) was formed in 2002 to test the feasibility of using hatchery-reared juveniles to replenish the spawning stock of mature females. BCARC emphasized integration of research on basic biology, hatchery technology, and experimental field releases of tagged juvniles for responsible stock enhancement. Over 8 years of funding totaling US$15million, BCARC significantly increased knowledge of basic physiology and ecology of blue crabs, and successfully developed hatchery technologies to complete the life cycle and produce cohorts of 20 mm juveniles for field experiments. From 2002-2010 we tagged and released 57 cohorts of 2,000-25,000 tagged hatchery-reared juveniles (378,000 crabs total) into nursery habitats of upper Chesapeake Bay plus nearly 150,000 juveniles in the lower bay. Releases resulted in averages of ~300% enhancement, ~15% survival, and production of ~300 adults ha^{-1}; but these averages varied significantly among sites and years, allowing development of optimal release strategies.

By 2008, the fishery was declared in a state of emergency. Traditional fishery management approaches over 15 years had failed to restore the depressed stock. BCARC's research demonstrated successful enhancement at small scale, and clearly showed that the stock was recruitment limited; but funding sources refused to commit additional support to scale up the enhancement approach. In a dramatic shift in management approach, fishing pressure on mature female crabs was greatly reduced by prohibiting fishing on the spawning stock in winter as well as summer. A major increase in juvenile recruitment occurred in 2009, which is now translating into significant recovery of the stock in 2010.

In summary, the BCARC researchers and the fishery managers took separate approaches that were not well coordinated. Each approach had major successes: (A) 8 years of research on stock enhancement provided an excellent example of integrating hatchery and field testing for successful enhancement strategy; (B) a major change in fishery management to reduced fishing pressure on females resulted in a recovery of the stock. However, research on aquaculture, stock enhancement, and fishery management is severely underfunded in the USA. In the blue crab case, the stock enhancement researchers and fishery managers did not cooperate enough, and have now lost the combined synergy to deal with future problems, as well as the momentum to build a stronger base of funding. Key recommendations resulting from this experience include: (1) the need for appropriate mutually agreed metrics of stock enhancement and for stock assessment; (2) the need for early incorporation of economic models into fishery management for regulatory, aquaculture and enhancement approaches; and (3) the need for much increased funding for all three approaches, commensurate with the value of the fishery.

Keynote: Comprehensive case studies

13&14. THE BIOLOGY, CULTURE AND ENHANCEMENT OF SWIMMER CRABS *PORTUNUS TRITUBERCULATUS* IN CHINA

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The swimming crab *Portunus trituberculatus* supports a large crab fishery and aquaculture in China, with total annual aquaculture production in 2010 exceeding 100,000 tons from 40,000-ha of ponds and a fishery catch of 80,000-100,000 tons in coastal waters. In this paper, we review the research on *P. trituberculatus* in China and compare it with research on the blue crab (*Callinectes sapidus*) in Chesapeake Bay USA.

Distribution and genetic selection research

P. trituberculatus is distributed throughout the coastal seas of China including the Bohai, Huanghai Sea, East China Sea, and South China Sea covering the coastlines of the Liaoning, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, and Fujian provinces. Swimming crab aquaculture is concentrated in the Zhejiang, Jiangsu and Shandong provinces. With the rapid development of Chinese aquaculture in recent years, considerable research has focussed on genetic selection to establish natural variability in crab population structure using mitochondrial DNA and microsatellite markers. From 617 base pairs of the mitochondrial DNA control region, we determined that the population from Yingkou, Dandong, Laizhou and Beihai had less genetic diversity (estimated by genetic distance) than that from Ningbo, Lianyungang, Qingdao and Japan. A computer program that provides geneologies from statistical analysis of genetic similarities suggested that all the sampled crabs probably resulted from recent divergence from a common ancestral haplotype, except for the Laizhou population. The haplotype distribution correlated with a recent colonization followed by localized genetic differentiation. Mismatched distribution results suggested that Ningbo, Yingkou, Qingdao, Lianyungang and Japan populations, and particularly the Dandong population, had experienced a sudden demographic or spatial expansion.

In another study, a statistical discriminant analysis of 14 morphological characters of *P. triberculatus* from four locations (Laizhou Bay, Yalu River estuary, Haizhou Bay, and Zhoushan Bay) was able to separate the geographic populations with 87% accuracy. However, variations in morphological traits were not characterized at the subspecies level. Although allozyme polymorphisms showed no significant differences among the four wild geographic populations, a dendrogram based on the genetic distances showed two different groups: one composed of Yalu River estuary and Laizhou; and the other of Zhoushan and Haizhou Bay. Eight polymorphic microsatellite loci were used to analyze the genetic diversity in the four populations, indicating a high-level of genetic diversity within each population. High genetic differentiation was observed between the Laizhou Bay population including the Bohai Sea and Yalu River estuary population extending north of Yellow sea and the other two populations. A lower degree of significant genetic differentiation was observed between the Haizhou Bay population in the Yellow Sea and the Zhoushan Bay population in Eastern China Sea. The results have important implications for the breeding management, as they indicate each locality constitutes a different stock for selection.

Reproductive biology and hatchery techniques development

The reproductive biology of swimming crabs in China has been studied since the 1960's (Shen, 1965). In the East China Sea, females reach maturity at a weight 200-400g weight and carapace width of 14-19 cm. The smallest mature male crab is over 10 cm carapace width. The maturation molt and mating peaks in September to October, while spawning peaks from March to April, with females producing 1-2 million egg per spawning. Reproductive output and larval quality are significantly higher for wild-caught crabs than for pond-reared crabs (Wu et al, 2010). Two approaches are used for hatchery production of second instar juveniles (crab II): (1) intensive larviculture in indoor concrete ponds, with temperature control, aeration, and a plentiful supply of food (algae, egg yolk, rotifers, *Artemia nauplii*); and (2) outdoor extensive larviculture in earth ponds with no temperature control. Outdoor production starts with crab II at a stocking density of 135-165 kg/ha and crab size of 20,000-24,000 juveniles/kg. Because wild-caught broodstock is preferred for juvenile production, the removal of females from wild stocks for hatcheries may become limiting for both crab aquaculture and natural recruitment of wild stocks and fishery production. The use of domesticated stocks for hatchery production is the key to overcome these constraints and also to facilitate genetic selection for desirable traits, such as rapid growth or pathogen resistance.

Selective breeding strategies

To develop a faster-growing cultured line of *P. trituberculatus*, China is using a selective breeding strategy both among and within families using full- and paternal half-sib matings that employ artificial insemination of multiple females with sperm from the same male. After mating, the females are transferred to indoor ponds to overwinter until spring brood production and larval rearing. Larvae are raised separately,by family, until they reach the juvenile II stage, when samples of each family are transferred separately to outdoor ponds. Important progress in marker-assisted selection was made during this breeding selection research. To date, a total of 151 full-sib and 26 half-sib families have been produced in the program. In 2008 a new "Huangxuan No. 1" line was selected for 13.9% faster growth than the natural population. In 2009-2010, families were selected successively to complement the initial "Huangxuan No. 1" line. Under 5% selection intensity, key production traits improved, including 20.1% faster growth. 51.2% better survival, and 71.2% increased yield. With support from the government fishery agency and crab farmers, the new line "Huangxuan No. 1" is being popularized in northern provinces of Weifang, Rizhao, Qingdao and Yantai in Shandong. Druing 2005-2010, approximately 2,000 ha were added to production of the new genetic line with considerable economy benefit.

Current stock enhancement

Since the 1990s, *P. trituberculatus* landings have declined markedly in East China Sea and Bohai and Yellow Seas because of overfishing, destruction of coastal spawning and nursery grounds and pollution. While the decline in natural stocks and increase in market demands have driven aquaculture interests for 20 yr, the Chinese government recently began funding stock enhancement of the swimming crab to stimulate the recruitment of wild stocks. Since 2005, fishery production has increased by more than 30% and the value of the fishery has exceeded the costs of enhancement by a factor of up to 10-fold. This rate of return has been achieved with very little research on stock assessment and crab ecology, and contrasts with the approach taken to blue crab enhancement in the USA.

Current advancements in aquaculture

Outdoor pond-culture of swimming crab has spread quickly along coastal regions of east China since the 1990s, but is concentrated in Zhejiang Province, where crabs are fed mainly the trash fish, and Jiangsu Province, where the food is both trash fish and low value bivalves, such as *Mytilus edulis*. Pond stocking densities of 45,000-150,000 crab II juveniles/ha results in 10-30% survival and production of 450-1,500 kg/ha. Crab production is by 8-100% by polyculture of several species in combination with crabs, including shrimp (*Exopalaemon carinioauda*, *Fenneropenaeus chinensis* and *Litopenaeus vannamei*) and clam (*Sinonovacula constricta*, *Mactra an*tiquate). Pond polyculture methods also exploit natural foods (algae, rotifers) for larvae, as well as fish (*Sparus macrocephalus*) to prey upon diseased shrimp and crabs, helping to prevent spread of disease.

15. STOCK ENHANCEMENT IN GREENLIP ABALONE: POPULATION AND ECOLOGICAL EFFECTS

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Stock enhancement experiments were carried out on *Haliotis laevigata* populations. Methodologies included a large-scale BACI experiment (42 sites), a carrying capacity experiment, which involved a high-density release at 2 sites, and a detailed survey of abalone populations and ecological parameters. Increased densities were detected for most age classes, although fishing mortality began obscuring the effect by age 5+. Age 4+ animals showed the clearest result, with no difference between enhanced and control sites at 6, 12, and 18 months post-release, and then a 300% increase at enhanced sites at 30 months post-release. Overall, this single release of Age 1+ animals in May 2006 had doubled the total density by November 2008. In the carrying capacity experiment, densities initially increased rapidly (by up to 800%), however had stabilised at a 400% increase after 2.5 years (2 to 8 per m^2), with the enhanced cohort representing 50% of the population. A PERMANOVA analysis of ecological similarity detected no effect of enhancement, although changes in algal % cover were detected at both control and enhanced sites. Overall our study suggests that, as long as release densities are controlled within natural limits, successful stock enhancement can be attained for this species, with minimal ecological impacts.

16. BIOLOGICAL PERFORMANCE AND GENETICS OF RESTOCKED AND WILD BLACK BREAM IN AN AUSTRALIAN ESTUARY.

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This study describes the results of a long-term investigation into the biological performance and genetics of restocked and wild black bream (*Acanthopagrus butcheri*) in the Blackwood River Estuary in south-western Australia. The restocking was done in 2002-03 and involved the release of juveniles of black bream, cultured using broodstock from the Blackwood River Estuary, in an attempt to replenish a heavily depleted population of this species in this system. The results of an investigation into the biological performance of the restocked fish for 3.5 years after their release into the estuary have already been published. This study builds upon this early work by providing information about the growth rates of restocked and equivalent wild individuals for eight years post-release, the proportion of restocked individuals reaching maturity, and the contribution of the restocked individuals to the gill-net fishery for this species in the estuary. It also includes the first information on the genetic consequences and implications of this restocking. The results demonstrate that the restocking of the black bream in the Blackwood River Estuary has been very successful in most respects and highlight the value of long-term monitoring in fish restocking programs.

THEME C: Governance and the socio-economics of releases

17. GOVERNANCE MECHANISMS AND SOCIO-ECONOMIC CONSIDERATIONS FOR COMMUNAL SANDFISH SEA RANCHING IN THE PHILIPPINES

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Holothuria scabra, commonly referred to as sandfish, is currently the only commercially important tropical species that is mass cultured. Aside from the use of cultured sandfish for stock enhancement, sea ranching has been proposed as a means to provide supplemental income for small-scale fishers. Given the open access nature and multiple users of municipal waters in the Philippines, governance mechanisms and socio-economic considerations to minimize social conflicts and sustain sea ranching efforts are essential. Three communal pilot sea ranching sites were established in the provinces of Pangasinan and Zambales in north-western Philippines. To legitimize the establishment of the sea ranch, a gratuitous permit, supported by a legislative resolution from the local government, was acquired by community partners. Sea ranching was integrated within a resource management framework to benefit both the rights-holders and other members of the community. The sea ranch co-operators are fisher families with an average annual household income of US$ 1800. Each group belonged to an organization with shared experience in community based coastal resource management in their respective communities. Kinship and their long histories of friendships are the basic foundations for cooperative arrangements. Because of their involvement in managing protected areas and fishery law enforcement, the groups have good working relationships with their respective local governments. The ranch managers developed a system to ensure 24/7 guarding in the sea ranch and participated in the monitoring of the sandfish population. They hold regular monthly meetings to discuss management concerns and the schedules for guarding. Sharing of income from the harvests is proportionate to the level of effort and time invested by the members and a portion is contributed to the village council. Dialogues with other resource users and dissemination of information about the management rules help deter and minimize poaching incidents. Only sea cucumbers > 320 g are harvested. If multiple batches of juveniles (>3g) are released in year 1, the first harvest can made after eighteen months and two other harvests every six months thereafter. For a total of 16,000 juveniles released with an overall survival rate of at least 19%, the estimated total yield of dried sea cucumber is 173 kg (US$ 10,500). The co-operator's share for two years is 18-29% of their annual household income (Table 1). There are no substantial opportunity costs from the perspective of the co-operator's. In addition, the ecological benefits of sustaining a viable spawning population that can help replenish the wild population provide spill over benefits to other sea cucumber collectors.

TIME	Details/Description	COST	GROSS INCOME	NET INCOME	% Ave annual income from harvest
YEAR 1	Sea ranching establishment	(1)527			0
YEAR 2	1st harvest (18months) [47kg (n=599 ind)]	(2,3)845	2390	1545	9%
	2nd harvest (24months) [44kg (n=1238 ind)]	(3)45	4209	4164	23%
YEAR 3	3rd harvest (30 months) [82 kg (n=1204 ind)]	(2,3)445	3902	3457	19%

[1]Site Establishment = US$ 527
[2]Annual maintenance = US$ 800
[3]Processing = US$ 45

Table1. Estimated harvest and income (US$) from sea ranch relative to average annual income of 10 households.

18. RETURN ON INVESTMENT FOR A LOBSTER (HOMARUS AMERICANUS) ENHANCEMENT PROJECT IN ATLANTIC CANADA

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An experimental lobster (*Homarus americanus*) hatchery project initiated by a harvesters' association has produced and seeded over 1.2 million stage IV lobsters since 2002 in the southern Gulf of St. Lawrence (sGSL), Canada. Based on a Before-After-Control-Impact approach, the release of over 53,000 stage IV in 2004 significantly increased the 2005 1-yr lobster density in seeded reefs compared to controls, indicative of a good survival over the 1st winter. Furthermore, a significantly higher density for the 2-yr lobster in 2006 was also observed suggesting a good survival over several years of hatchery-reared animals after being released in the natural habitat. Using that information, a bio-economic model has been developed to assess the biological and economic benefits associated with lobster stock enhancement initiatives. The model has been used to calculate the return on investment (ROI) and economic impacts generated by an investment of $25,000 CDN to seed 100,000 stage IV. Results showed that this investment would on average increase landings by 18,288 kg and generate $144,471 over 10 years in increased revenues for harvesters, i.e., equivalent to a ROI of 18.4 %. The harvest and process of these lobsters would generate on average about 4.1 person-years of employment locally and 5.4 for Canada as a whole. The Gross Domestic Product generated would amount on average to $206,200 locally and $304,400 for Canada. Government tax revenues would, on average, reach $15,100 locally with an additional $38,200 for the Canadian government. Hence, simulations have shown significant economical benefits from the seeding of 100,000 stage IV lobsters. With this new information, harvesters' associations can make informed decisions about the profitability of lobster seeding.

19. REGULATING CATCH-SIZE TO SUPPORT ABALONE STOCK ENHANCEMENT INITIATIVES: EXPERIENCES IN SAGAY CITY, PHILIPPINES

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The study aims to determine a strategy for managing threatened and enhanced stocks of abalone in Sagay Marine Reserve (SMR) in the Philippines. The literature suggests that stock enhancement is ideally conducted in marine reserves to create best results. However, the management of marine reserves and most fisheries are challenged by fishing pressure due to poverty, high human population and lack of livelihoods in most coastal rural communities. Thus, stock release strategies should consider its co-existence with regulated human activities. However, the survey showed low level of awareness about stock enhancement and life-cycle of abalones and most fishery resources among coastal dwellers. This hinders the success potential of fisheries management initiatives. Lack of information is also associated with irresponsible fishing behavior such as capture of immature and undersized abalones. This socioeconomic component of the stock enhancement of abalone (*Haliotis asinina*) project of SEAFDEC/AQD and the GOJ-TF demonstrated and implemented strategies for regulating catch-size of abalones to complement on-going experimental release and future stock enhancement initiatives in Carbin Reef, a strictly no-take area within the SMR. The study demonstrated a framework for building collaboration and stakeholder ownership of regulations in a stock enhancement project.

Table 1. Roles and responsibilities agreed by stakeholders in Sagay Marine Reserve (SMR) for the abalone stock enhancement demonstration site in Barangay Molocaboc, Sagay.

SMR / Municipal LGU	Barangay Molocaboc LGU	SEAFDEC / AQD	Academe / Schools	Community/ People's Organization	Traders
Assist partners Community Organizing Law enforcement Resources management planning Project monitoring Conduct/ support IEC Benchmarking of resources	Provide manpower Enforce ordinance Implement IEC Assist in monitoring Coordinate with municipal LGU, SMR, BFARMC Enjoin youth participation Provide logistics Provide permit to collect broodstocks	Research, technical assistance & training Initial supply of seeds in demo site Provide scientific information in drafting fishery ordinances, resource management and aquaculture livelihood	Assist in data gathering Assist and complement IEC activities	Revitalize peoples organizations with assistance from LGU/SMR Actively cooperate in community projects Disseminate and comply with ordinance Provide labor (*bayanihan* style)	Support ordinance on catch size regulation Practice fair pricing Provide market information to SMR and SEAFDEC Contribute in demo site construction

20. ECOSYSTEM-BASED SEA RANCHING IN ZHANGZIDAO IN NORTHERN YELLOW SEA

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In the past two decades, Zhangzidao Fishery Group Co. Ltd has been practicing the idealism of "ecosystem is living' and establishing itself as a stock enhancement and sea ranching colossus in China. At present, Zhangzidao has been authorized to operate a sea area covering 1900 km^2 in northern Yellow Sea, and utilizes the area till a water depth of 50 meters. In recent years, about 7 billion seedlings of scallop, abalone, sea cucumber and other commercially important species were released into this area annually, at a total value of 500 million RMB. In 2010, 55 000 t scallop (*Patinopecten yessoensis)*, 1 500 t abalone (*Haliotis discus hannai)*, 400 t sea urchins and 550 t sea cucumber (*Apostichopus japonicas)* were harvested in Zhangzidao. Zhangzidao islands are composed of 9 islets, with a total land area of 14 km^2 only. In the past decades, Zhangzidao has evolved from a small fishery company into a world-level integrated seafood producing group corporation, from larva/ seedling rearing, farming, basically by sea ranching, to processing and marketing. To implement sea ranching as the developmental strategy in Zhangzidao is based on the ecological condition, scientific considerations and targeting at sustainability. Tremendous efforts were made to optimize or improve the ecological conditions in sea ranching areas, including seaweeds planting and propagation and properly construct artificial reefs. In recent years, Zhangzidao invests around 10 million RMB each year to set up artificial reefs in her authorized sea area to improve habitats for fish and seaweeds, remediate and optimize the ecosystem for scallop, sea cucumber, sea urchin, abalone and the other economically important organisms.

21. STOCK ENHANCEMENT AND RESTOCKING IN AUSTRALIA AND OPPORTUNITIES FOR FINFISH, PARTICULARLY IN WESTERN AUSTRALIA

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In this study, we synthesise information on marine and estuarine restocking/stock enhancement programs in Australia and evaluate potential opportunities for stock enhancement, particularly in Western Australia. In Australia, the scale of restocking and stock enhancement programs in marine environments has been low relative to those of other countries, particularly Japan, China and the United States. However, since the early 1990s, a number of government and industry organisations and the Fisheries Research and Development Corporation of Australia, have made significant investments in research and development programs for the release of a variety of species. The scale of these research programs has varied from releases of tens of thousands of individuals (greenlip abalone *Haliotis laevigata,* barramundi *Lates calcarifer* and mulloway *Argyrosomos japonicus*), hundreds of thousands (tiger prawns *Penaeus esculentus* and black bream *Acanthopagrus butcheri*) to millions (eastern king prawns *Penaeus plebejus*). These research and development programs, although not yet evolving to major release programs, have resulted in increased knowledge of the population

dynamics and ecology of released species and the development of bio-economic and energetic models to better plan and evaluate enhancement.

Currently, research and development activities are continuing in New South Wales (mulloway and eastern king prawns), Queensland (barramundi) and Western Australia (black bream *Acanthopagrus butcheri* and greenlip abalone *Haliotis laevigata*). Furthermore, Victoria is developing a plan for releasing juveniles in estuarine and marine environments and South Australia has developed a policy for marine and estuarine stock enhancement. Policies on stock enhancement are being considered for development in New South Wales and Western Australia.

The development of policies for stock enhancement in many of the Australian states has been a result of increasing coastal populations and fishing pressures in major urban centres. Interest in marine stock enhancement has increased in recent years, particularly from recreational fishers and the establishment of recreational fishing licenses in some states is providing a funding mechanism for enhancement programs. In Western Australia, major developments of energy resources are taking place in the sub-tropical and tropical marine environments, and this includes massive increases in infrastructure support e.g. ports and housing. Developers are required to purchase environmental offsets as part of the development process and funds from the offsets are being considered for the establishment of artificial reefs and stock enhancement programs. The Department of Fisheries WA lead a delegation to South Korea and China to explore the potential application of technology for artificial reefs and enhancement to be applied in Western Australia. Future opportunities and prospects for stock enhancement in Australia will be discussed.

22. ECOLABELLING AND ENHANCED FISHERIES: INTERNATIONAL GUIDELINES

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The use of market forces through ecolabelling and certification of fisheries and fish products is being promoted as one strategy to encourage sustainable fisheries. A variety of voluntary ecolabelling schemes have been established by governments and private groups that set standards to assess the performance of how a fishery is managed and how its products are handled. These schemes generally require a third party to assess the environmental impacts of a given fishery on the "stock under consideration", and the integrity of the chain of custody (traceability) in order to award an ecolabel, i.e. certify the fishery. The Food and Agriculture Organization of the United Nations (FAO) has established guidelines and standards for the ecolabelling of fish and fishery products from marine capture fisheries and guidelines for inland capture fisheries were adopted by the 29th Session of the FAO Committee on Fisheries in February 2010. Although the marine and inland capture fishery guidelines are similar, they differ in regard to fishery enhancements. Enhancement may entail stocking with material originating from fish culture installations, translocations from the wild and habitat modification. Enhanced fisheries are part of the continuum of fish production systems at one end of which are capture fisheries operating only on naturally produced fish stocks and at the other end are aquaculture facilities that control every phase of the organism's growth and reproduction with very little reliance on the surrounding ecosystem. Most ecolabelling and certification schemes specify whether they apply to capture fisheries or aquaculture and it is difficult to classify a production system that has components of both capture fisheries and aquaculture, e.g. culture-based fisheries. The use of enhancements is common in inland fisheries and, according to expert advice given FAO, under specific conditions enhanced fisheries can be within the scope of fisheries covered by the inland capture fishery guidelines. The marine capture fishery guidelines do not yet specifically address enhanced fisheries, though the related scope and minimum substantive requirements in the inland capture guidelines seem to be equally applicable to marine fisheries.

What kinds of enhanced fisheries are within the scope of international guidelines?

The scope of the inland capture fishery guidelines extends to enhanced components of the "stock under consideration" provided that a natural reproductive stock component is maintained and fishery production is based primarily on natural biological production within the ecosystem of which the "stock under consideration" forms a part. Specifically, to be within the scope of the guidelines, enhanced inland fisheries must meet the following criteria: the species are native to the fishery's geographic area or were introduced historically and have subsequently become established as part of the "natural" ecosystem; there are natural reproductive components of the "stock under consideration"; and for stocked material, growth during the post-release phase is based upon food supply from the natural environment and the production system operates without supplemental feeding.

Minimum substantive requirements for ecolabelling an enhanced fishery

Once an enhanced fishery is judged to be within the scope of the guidelines, the following minimum substantive requirements for a well managed enhanced inland capture fishery were developed:

The overall enhanced fishery should be managed so that the naturally reproductive components are managed in accordance with the provisions of the FAO Code of Conduct for Responsible Fisheries (the Code); aquaculture facilities providing material for stocking should also follow the Code, especially in relation to maintaining the integrity of the environment, the conservation of genetic diversity, disease control, and quality of stocking material. Removal of organisms from wild stocks other than the stock under consideration should also be managed according to the provisions of the Code. Significant negative impacts of enhancement activities on the natural reproductive components of the "stock under consideration" should be avoided. The naturally reproductive components of enhanced stocks should not be overfished. The naturally reproductive components of enhanced stocks should not be substantially displaced by stocked components. Enhanced fisheries should be managed to ensure biodiversity of aquatic habitats and ecosystems are conserved and endangered species protected. Any modifications to the habitat for enhancing the "stock under consideration" are reversible and do not cause serious or irreversible harm to the natural ecosystem's structure and function. We applied the scope criteria for inland capture fisheries to enhanced marine capture fisheries and then reviewed several enhanced fisheries both inland and marine as an exercise to determine whether or not they would be within the scope of fisheries eligible for an ecolabel.

Conclusion

Enhancements are becoming more common in marine capture fisheries, and the international community, with expert assistance, should review the marine capture fishery guidelines to help ensure that ecolabelling assessments of enhanced fisheries appropriately consider the potential environmental impacts of enhancement. The enhancement elements contained within the inland capture guidelines would provide a logical foundation for this review. Fishery products from different production systems and environments must compete on a level field in the market-place and consumers must be aware of exactly what an ecolabel stands for. Fishery managers of enhanced fisheries and associated fish culture facility operators should become familiar with these guidelines to promote well-managed capture fisheries as a further component of the responsible approach to fishery enhancements.

23. REGULATION OF SEA RANCHING AND ENHANCEMENT

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Sea ranching and enhancement have the potential to have a profound effect on the environment. Recognising that impact, it can be expected that sea ranching for private profit will be appropriately regulated. Most enhancement activities are however undertaken by government and commonly by the agency responsible for protecting and preserving the natural populations. They are usually adopted after an extensive investigation and debate about their impact but then with limited regulation or monitoring by an agency other than the agency that promoted the activity. This presentation suggests that in both cases adequate regulatory requirements should be implemented and a common set of regulatory requirements should be adopted. Sea ranching and enhancement have the potential to have a profound effect on the natural resource not only by significantly increasing the population available for fishing but in various negative ways. These impacts can include: the possible spread of disease; effect on the natural gene pool; carrying capacity of the seas; predator-prey relationship; the trophic interactions; management and co-management issues; and the effects of translocations and introductions.

In considering whether to permit sea ranching and enhancement, many facets require consideration beyond the social and economic benefits. These include:

the adoption of the precautionary approach and how it should be applied;
the preservation of the wild species of fish as a priority;
the fisheries management plan of the jurisdiction or region;
the aquaculture management plan of the jurisdiction or region;
the species to be released;
the possible spread of disease by the released fish;
the impact on existing wild populations and the fisheries;
the impact that the release of fish may have on the sea and on other users of the sea;
the impact on the gene pool of an existing species by the release of fish;
the carrying capacity of the sea or the region to be utilised for sea ranching;
the likely predation impact of the number of released fish in the sea or an area thereof;
the overall trophic effect of the released fish in the release area and adjacent waters;
the likely competition between the released fish and the wild populations;
the impact on the ability to manage the wild populations of fish;
the ability to readily identify and distinguish the released fish from other released fish and the wild fish to facilitate the management of the various populations;
ensuring an appropriate balance is maintained between the wild species and the released fish having regard to the priority to be afforded to the wild species;
any economic benefits or dislocations that will be suffered by the communities in the area where the fish are to be released and/or recaptured; and
any likely impact that the proposed sea ranching activity will have on neighbouring jurisdictions or any other jurisdiction likely to be affected.

Even more complex considerations will arise if the species to be released is an alien animal in the place of its release. Once it has been decided that sea ranching or enhancement may be undertaken the following matters should be considered:

the number of each species to be released in each year;

the region in which the releases are to be made;
the time or times when the releases are to made;
the likely migratory patterns of the species to be released;
where sea ranching is involved, the methods to be used by the sea rancher to recover the fish released by the sea rancher;
the method of marking or branding the fish to be released;
the source of the fish to be released;
the methods to be used to ensure the disease-free status of the fish to be released;
the methods to be used to ensure a suitable genetic mix of the population to be released;
the methods to be used to ensure minimum reproductive capacity of the fish to be released, where that is necessary;
a basic management plan for the proposed sea ranching operations and its conduct;
the manner of preservation of property rights in the released fish;
resource rent payments for utilising the common resource in sea ranching;
managing resistance to such activities;
where acoustic or other like devices are intended to be used as part of the sea ranching activities the impact of the use of those devices must be considered and regulated;
appropriate monitoring programs; and
appropriate cost benefit analysis reviews and reviews of achievements against target objectives, both as part of a regular review of the enhancement program.

Summary

Sea ranching and enhancement offer opportunities but have the potential to have a profound impact on the environment. The adoption of either should only occur after adequate investigation and thereafter within an adequate regulatory framework.

24. THE LONG AND WINDING ROAD IN SEA RANCHING

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Two communities in southern Philippines are being involved in a sandfish sea ranching project which is funded by the ACIAR and the national government. The project is ending its four-year implementation. This paper shares what is working and not working among the project partners who bring in their respective interests and have to operate under a highly bureaucratic government system. Engaging the private sector facilitates logistics in the field but can be a political deterrent. There is no substitute to a fully supportive local government; the downside is when leaders change after a local election. The fishers group is the most vulnerable partner in the sense that their enthusiasm can wane during the long wait for that first harvest, especially when they are confronted between guarding the sea ranch and earning a living for the day; between meeting the day-to-day needs of the family and making a long term commitment for the sake of a 'common good'.

THEME E: Interactions between wild and released animals and their ecological and genetic implications

25. OVERLAP OF HOME RANGES OF RESIDENT AND INTRODUCED SOUTHERN ROCK LOBSTER AFTER TRANSLOCATION

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Translocation and sea-ranching are under scrutiny as methods to augment populations so that harvests can be increased or populations can better adapt to changing environmental conditions. Understanding the ecological effects of any such environmental manipulation is critical to its' successful application. One potential ecological effect of any type of stock enhancement is the displacement of either resident or the released groups such that finding shelter or foraging habitat is adversely affected. We examined behavioural interactions of resident and translocated *Jasus edwardsii* rock lobster after an introduction of 1,961 'small pale' phenotypic morphs to an area populated by the resident 'large red' phenotypic morph. This translocation was an experimental stock enhancement conducted as part of a larger study to increase the yield and value of the fishery. Most translocated individuals established home range within a couple of days of release (generally <2) and these ranges were generally less than 1.0ha in size. Home range kernels and foraging ranges overlapped between the two morphs, and there was no evidence of avoidance (Jacob's cohesion index 0.01, Z=1.06, p=0.28). This case of translocation for stock enhancement between ecotypes had no detectable adverse effect on either the resident or the translocated population, and in this species stock enhancement could become part of an integrated conservation and harvest optimisation strategy.

26. GENETIC TAGGING OF FARMED ATLANTIC COD (*GADUS MORHUA* L.) AND DETECTION OF ESCAPEMENT FROM A COMMERCIAL COD FARM

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Farmed fish are escaping from the aquaculture industry and this is considered a risk for negative genetic impacts on native gene pools. A genetic tagged Atlantic cod (*Gadus morhua* L.) strain was developed to identify escapees from commercial cod farms and to investigate the potential interbreeding between farmed and wild cod. The genetic tagged cod are homozygote for a rare allele in the *GPI-1*30* locus expressed in white muscle tissue. Large quantities of offspring were produced from this strain in 2007 and 2008, and 500 000 juveniles of each year-class were transported to a cod farm in western Norway, where they were raised under commercial conditions. A comprehensive monitoring fishing program was established to detect escapees during the farming period. All cod captured around the farming facilities and in the adjacent fjord areas were screened for the genetic tag. The first farmed cod escapees, identified to the 2008 year-class through the genetic tag and body size, were found around the farming locations and in the adjacent fjord area in November 2008. The second and larger escapement of the same year-class was detected during the natural spawning season in early April 2009. A third escapement was detected in November 2009, and this time the farmed cod were identified to the 2008 year-class. The escapees of the 2008 year-class were spreading in the whole fjord system, including local spawning sites for wild cod. Detailed examination of the escaped cod revealed substantial degree of sexual maturation, and 869 cod larvae were therefore collected through spring 2009.

The genetic analyses identified 8 larvae as offspring from the escaped farmed cod, demonstrating successful reproduction under natural environmental conditions. But so far, no significant signal for interbreeding has been detected.

27. GENETIC INTERACTIONS BETWEEN WILD AND HATCHERY RED SEA BREAM CONFIRMED BY MICROSATELLITE GENETIC MARKERS

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Millions of red sea bream juveniles have been annually released throughout the Japanese Archipelago over the last decades. Releases have contributed to the harvestable stocks of this commercially and culturally important species; however, little emphasis has been placed upon addressing introgression between wild and hatchery-reared fish in a large-scale. In contrast to freshwater or low-range migratory species, red sea bream in Japan comprises a single "large" panmictic stock where specimens undertake long-distance migrations. This fact makes difficult to elucidate the magnitude of the contribution of enhancement programs, requiring large number of high-polymorphic markers such as microsatellites. In this study, twenty microsatellite markers were genotyped to overcome the limitations and characterize the genetic profiles of 1098 red sea bream collected at 16 locations and 4 hatchery strains. The analysis reinforced the hypothesis that red sea bream in Japan comprises a single panmictic stock. However, evident signs of genetic differentiation, likely related to the releasing history of the species, have been detected at two locations. Therefore, these results stress the need to monitor and revise the effectiveness of large-scale releases in long-term, including the genetic interaction between wild and hatchery specimens.

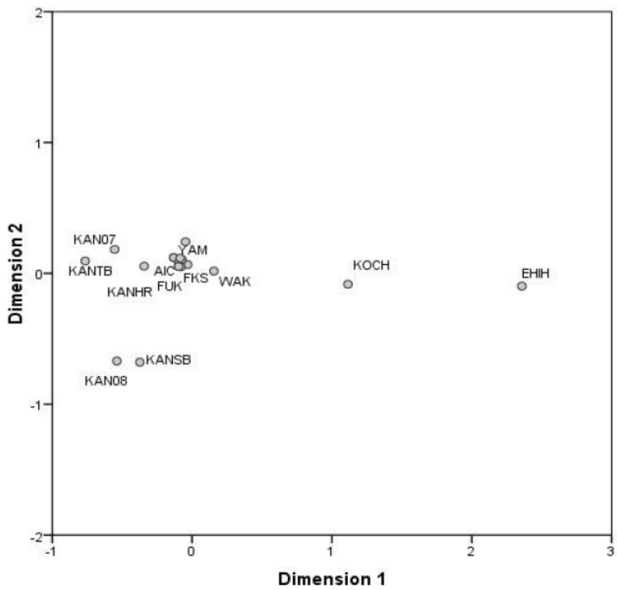

Fig. 1. MDS plot based on pairwise genetic differentiation (*F*ST) among samples.

28. ECOLOGICAL AND GENETIC IMPACTS OF BARRAMUNDI (LATES CALCARIFER) STOCKING IN NORTHERN AUSTRALIA

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Baramundi (*Lates calcarifer*) have been stocked into northern Australian waterways since the mid 1980s for stock enhancement and to create new impoundment fisheries. Fisheries managers and other interest groups are now concerned that these stockings are impacting on aquatic ecology and on the genetic diversity of wild *L. calcarifer* stocks in coastal river systems. Particular concerns have been expressed about the potential effects these introductions are having on fauna of conservation concern. To address these issues, an experiment to determine the diet, movements and the genetic impacts of the release of stocked barramundi commenced in late 2009. This experiment involved the release of about 13000 marked 0+ barramundi into different habitats in a northern Australian coastal river and into a large impoundment. These stockings are being monitored using routine six weekly electrofishing surveys. Preliminary gut content analyses of these fish found those in the coastal river were consuming crustaceans (*Macrobrachium* spp. and atyid shrimp) while fish were the dominant prey of impoundment *L. calcarifer*. The stocked 0+ fish resident in the coastal river showed strong site fidelity, with no evidence of either these fish, or the impoundment barramundi, moving into lower order streams in environmentally sensitive areas. There was also no evidence that they were preying on fauna of conservation concern. Older fish from previous stockings moved downstream into estuarine and coastal areas with some fish making inter-riverine movements. DNA parentage analyses are also being used to assign stocked juveniles to their family of origin. This is being done to determine if differential family survival occurs thereby lowering the overall genetic diversity of stocked groups. Recaptured stocked fish mostly showed relatively even representation across hatchery family groups, although a dominant family group representing 35% of the fish that were originally stocked into the river was absent from subsequent recaptures.

29. SUMMARY/DISCUSSION

KEYNOTE: Species interactions

30&31. REARING AND GENETIC EFFECTS ON FITNESS OF ARTIFICIALLY-PRODUCED ANIMALS IN THE WILD: EMPIRICAL EVALUATION OF LARGE-SCALE FISHERY STOCK ENHANCEMENT PROGRAMS

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In conservation and population management programs, a release of artificially-produced animals is one of the most popular tools. Produced animals released into the natural environment (hereafter "in the wild") interact with wild ones depending on the carrying capacity, and therefore should be compatible with wild ones in successful release programs. Since the late 1980s, there has been growing concern about the ecological and genetic effects of hatchery-reared fish on wild populations. One major source of concern is the replacement of wild fish by hatchery fish. Another concern is the deleterious genetic effects of hatchery fish on wild populations. Anomalous genotypic and phenotypic traits have been observed in hatchery populations since the early 1980s. Significant losses of genetic variation or changes in genotypic frequencies in hatchery populations have been reported for several species. There has been a general increase in awareness of the loss of genetic variation in hatchery populations.

The essential concern is whether the loss of genetic variation causes loss of fitness of hatchery and wild populations. Reisenbichler and McIntyre (1977) first found that the survival of hatchery-produced steelhead *Oncorhynchus mykiss* was lower than that of wild fish in natural streams. Recently, Araki *et al*. (2007a, 2007b), using microsatellite parentage assignments, discovered a considerable reduction in the reproductive success (RS) of hatchery-reared steelhead (F1 fish) when they bred in the wild. Araki *et al*. (2009) also found a carryover effect with an even lower RS in hatchery descendants (F2 fish born in the wild). The lower RS of hatchery fish could result in a reduction in reproductive potential of stocked populations when released fish significantly contribute to the population. However, the mechanisms causing the reduction in RS of steelhead are unknown, and it is not clear to what extent these results extrapolate to other species (Araki *et al.* 2009).

To address this issue, we investigated the causes of the lower RS of hatchery-reared steelhead, and whether the reduction in RS could be generalized to other species. We first tried to extend our understanding of the results of Araki *et al.* (2007a, 2007b, 2009). We then explored the statistical properties of the relative reproductive success (RRS) estimator on the basis of empirical RRS estimates of the steelhead. From this analysis, we hypothesize that rearing in a hatchery over one year affected the reproductive behavior of hatchery-reared steelhead, which resulted in the low RRS. We then examined whether the fitness reduction of hatchery-reared animals occurred in other species using three different types of large-scale release programs from Japan; the chum salmon *Oncorhynchus keta* (conducted over 100 years) and Japanese scallop *Mizuhopecten yessoensis* (~40 years) in Hokkaido, and red sea bream *Pagrus major* in Kagoshima Bay (KB) (~35 years), in which the impact of released fish to the commercial landings was significant and genetic monitoring was conducted.

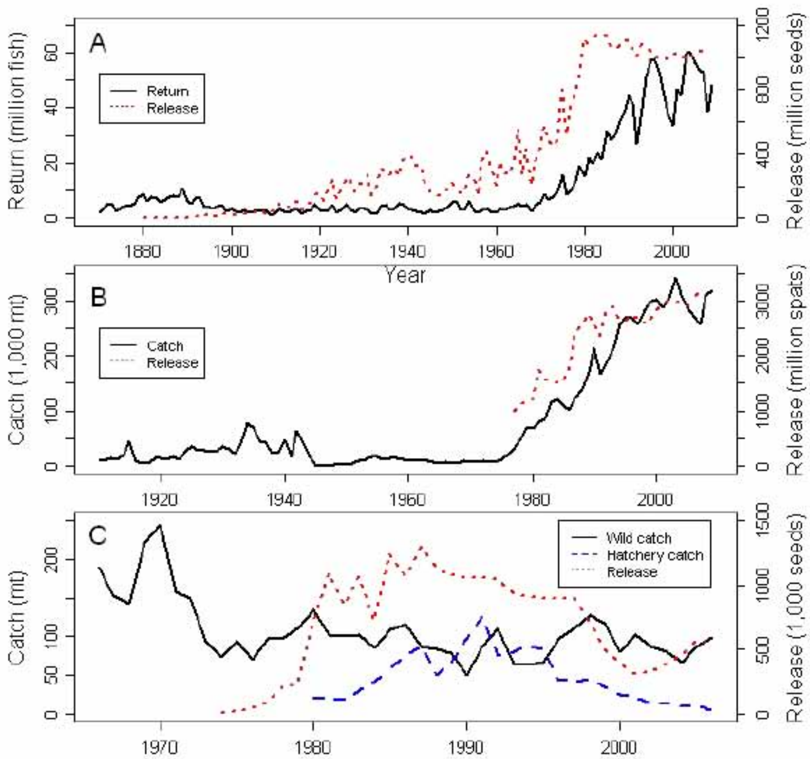

Fig 1. Catch and release statistics for A: Chum salmon and B: Japanese scallop in Hokkaido, and C: red sea bream in Kagoshima Bay

The number of chum salmon returning and the catch of scallop have increased above historical levels with the increased number of individuals released (Fig. 1A, B). The commercial catch of released red sea bream in KB also increased after the start of the program, but has continued to decrease since early 1990, along with the decreased number of released fish. On the other hand, the wild catch has generally remained above the catch level at the commencement of release (Fig. 1C).

Most of the annual catch of chum salmon has been created from hatchery fish. Chum salmon returning to spawn are used for artificial propagation every year. Therefore, the case of chum salmon examines the effect of 3–4 months rearing on smolt-to-adult survival of hatchery fish (C[C×C], see Araki et al. 2007a). Catches of Japanese scallop consist of released individuals and wild descendants reproduced from released spat. Naturally-born scallop larvae are collected and bred in net cages for one year in the wild before release. The case of scallop examines the rearing effect on survival and the RS of released spats (C[C×C], C[C×W], C[W×W]) in the wild. The red sea bream program in KB has used nonlocal parents and their progeny for multiple generations kept in concrete tanks. The contribution of hatchery fish to commercial landings in inner KB (IKB) was high at 41.2 ± 26.8% during 1989 and 2004. The time for rearing before release is about 100 days, 50 days in concrete tanks and 50 days in net cages. The case of red sea bream examines the effects of both juvenile rearing and domestication selection of breeders during several generations on survival and RS of hatchery fish (C[C×C]) in the wild.

The increased return rate and the fishery production of chum salmon demonstrated no decline in smolt-to-adult survival in hatchery-reared fish. High survival rates and increased fisheries production of scallop also showed no reduction in survival and RS of released spat. In contrast, the recapture rate for one-year-old red sea bream decreased consistently, suggesting a decline in the survival rate of hatchery fish born from broodstock used to rear multiple generations. The result suggests that hatchery-reared red sea bream were affected by domestication selection of breeders and weaker fish were removed by natural selection in the wild. Nevertheless, the wild catch of red sea bream has generally remained above the catch level at the commencement of release, with a high genetic mixing proportion of hatchery fish in IKB (39.0% ± 73.8%). These results suggest that the juvenile rearing effect and domestication selection of breeders on survival and RS were cancelled by natural selection. A longer rearing duration in a hatchery decreases the effect of natural selection in early life stages, in which natural mortality is very high in aquatic animals. Empirical data teaches us that hatchery-reared animals with relaxed natural selection in captivity are again exposed to natural selection in species-specific survival and reproductive processes with wild animals.

THEME D: Developing optimal release strategies

32. CARRYING CAPACITY IN JUVENILE STAGES OF EUROPEAN LOBSTER (*HOMARUS GAMMARUS*); ESSENTIAL KNOWLEDGE FOR RESTOCKING/SEA RANCHING

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Carrying capacity in an ecological perspective can be defined as total number of individuals of a population a given environment can sustain. In aquaculture it refers to the potential maximum production that can be maintained within an area relative to available food and environmental resources. Carrying capacity can eventually reach a limit and thus reduce the production, either due to perturbations of the environment or to overexploitation of the food source. Lobster is highly valued seafood and has been commercially harvested along the coast of Norway for centuries. Declining wild populations have resulted in renewed interest in restocking as well as sea ranching. Wild juvenile European lobster (*Homarus gammarus*) smaller than 40 mm carapace length have rarely been captured, hence we have no knowledge of neither preferred substrate the juveniles live on/in nor carrying capacity. Previous experimental studies on early benthic phase indicated preference to settle in a complex substrate of sand/cobble. The sheltering behaviour in these early-life stages is considered an antipredator response. Knowledge of the early benthic stage of European lobster is considered crucial for restocking and sea ranching endeavours. A series of experiments were run aiming to estimate juvenile density under controlled conditions. Pelagic stage IV larvae were released at densities from 10 to 40 per m2 into tanks stocked with shell

sand and shelter. After 8 months, the various experiments yielded from 8 to 20 juveniles per m2. Highest mortalities were found in the experiments with highest release density (82%). There were indications that the carrying capacity had not been reached in the experiments with lowest release density. This was also the experiments with lowest mortality (32%). Perspectives of possibilities to further increase the carrying capacity will be discussed.

33. ESTABLISHING RELEASE STRATEGIES FOR STOCK ENHANCEMENT OF HATCHERY-REARED ABALONE *HALIOTIS ASININA*

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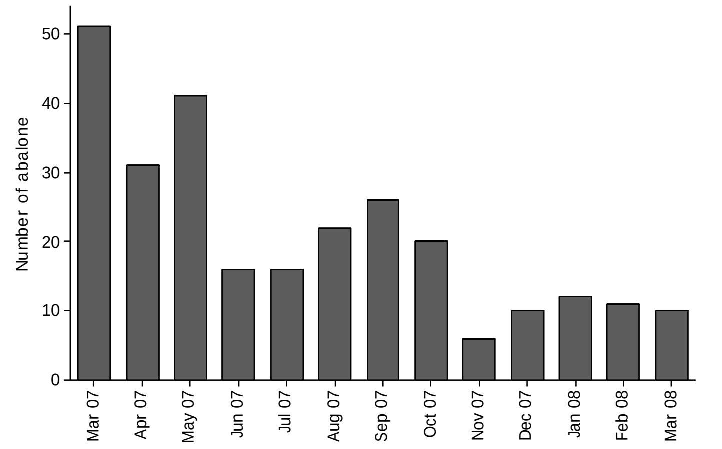
The lucrative returns brought by abalone fisheries have caused overexploitation and decline of the wild population. In the Philippines, the Southeast Asian Fisheries Development Center Aquaculture Department has successfully developed the hatchery technology and completed the life cycle of the donkey's ear abalone *Haliotis asinina*. Success in hatchery production has also led to the development of different grow out techniques. However, production of abalone in aquaculture facilities does not benefit the marginalized fisherfolks who comprise majority of the fisheries sector. This study aimed to enhance abalone population in Carbin Reef Sagay Marine Reserve through release of SEAFDEC/AQD hatchery-reared (HR) juveniles.

Fig. 1. Monthly samples of Haliotis asinina in Carbin Reef, Sagay Marine Reserve (Mar 2007-Mar 2008).



Prior to release, a 13-month baseline assessment of the wild population was conducted in 10 50 x 2 m belt transects. Results showed decreasing abalone density from March 2007 to March 2008 (Fig. 1). There is a significantly positive correlation of abalone density with branching corals with epiphytic algae cover (Pearson correlation = 0.73; $p<0.05$) showing their preference to this type of substrate. The coral branches provide shelter and the algae are utilized food.

To test the viability of HR abalone in the wild, initial release of 1,010 diet-tagged individuals, 2.1-3.0 cm shell length (SL) was done in July 2008. During the acclimation process, higher mortality was observed in abalone smaller than 3.0 cm SL. Mortality was highest on the day of transport (13.27%) which decreased until day 3 (0.30%). Abalone stayed inside or on the transport pipes until day 7, during which all abalone moved to the corals and other available shelters on the reef. From the recaptures, HR abalone showed higher growth rate (0.27±0.04 cm mo^{-1}) than the wild ones (0.13±0.04 cm mo^{-1}). Hatchery-reared abalone were recaptured until 511 days post release. Results of this preliminary release trial revealed that HR abalone are viable for release in the wild and can survive with their conspecifics. Moreover, a second release was done in August 2010 improving the protocols used in the first release. Results of the second release were more promising than the first with lower acclimation mortality, higher recapture rates and better survival.

34. *Trochus niloticus* TRANSLOCATION: PROSPECTS IN ENHANCING DEPLETED PHILIPPINE REEFS

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The introduction of *Trochus niloticus* to many isolated islands in the Pacific has expanded its limited distribution range, and it has become an important resource in some of those areas. By contrast, the species is now threatened in the Philippines where it is endemic. Although trochus fishing is now prohibited, uncontrolled exploitation continues, further pushing its remaining populations to the verge of extinction. Trochus have limited mobility and a short larval period so that population recovery in overexploited offshore reef areas could be impossible even after fishing intensity is reduced. Trochus enhancement through the release of hatchery produced juveniles may not be feasible because of high cost and low survival rates. But the translocation of wild trochus appears promising with high survival rates and high growth rates at some sites. Trochus reintroduction to a network of well managed marine reserves is therefore a potential option to revive the country's depleted reefs. Trochus plays an important role in the food chain and its revival can further enhance reef biodiversity. The success in reviving trochus population by translocation may pave the way to similar conservation strategies for other reef invertebrates.

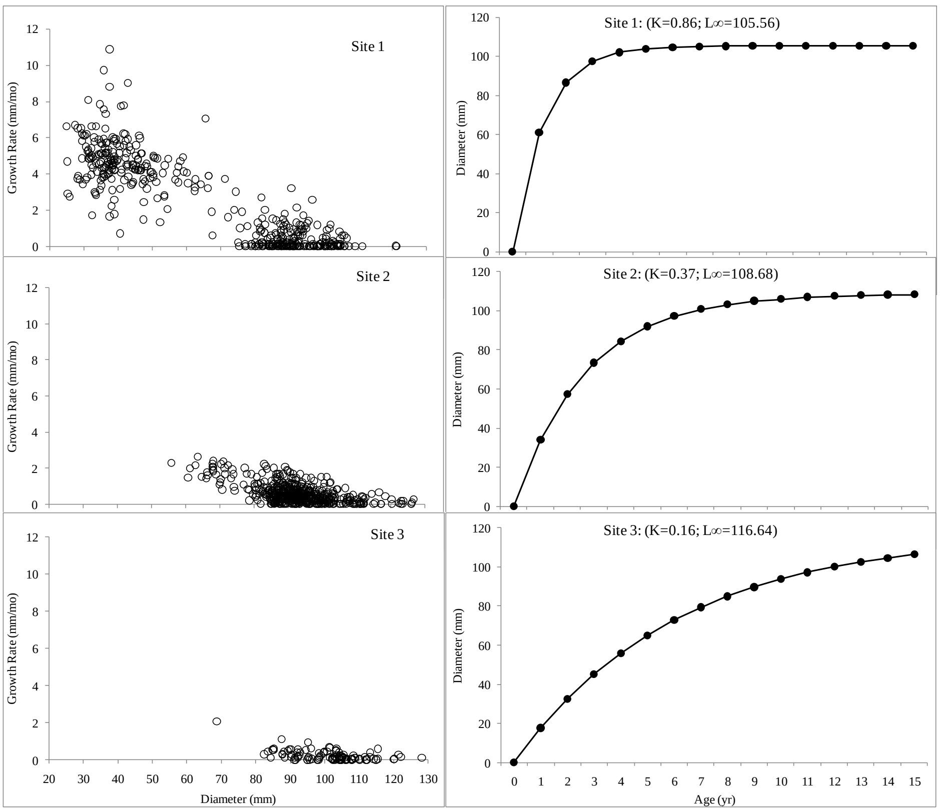

Figure 1. Scatter graphs (left hand side) between the monthly growth rate (mm mo^{-1}) and median (measured as the mid-point between the sizes at tagging and recapture or sizes at previous and succeeding recapture) shell diameter (mm). On the right hand side

are the projected diameters (mm) at age (year) of trochus in the three sites obtained using the von Bertalanffy growth formula.

35. IMPACT OF FENCED SCALLOP (*PECTEN MAXIMUS*) SEA-RANCHING ON BENTHIC FAUNA

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Sea ranching of the great scallop (*Pecten maximus*) in Norway is done by release of hatchery-reared spat to the seabed. The release areas are bordered by fences to prevent predatory crabs (*Cancer pagurus*) access to the scallops (Figure 1). A fence (50 cm high) of solid plates or plastic canvas is shown to be sufficiently efficient to obtain high scallop survival. Scallop sea-ranching is regulated under the Norwegian Aquaculture Act where measures are set to contribute to a sustainable development of the industry. The Institute of Marine Research aims to provide scientific knowledge on ecological effects from scallop sea ranching. Using fences on the seabed to prevent a target predator access to the area may also obstruct other mobile fauna, and the fence combined with high scallop density within the farmed area may influence the benthic fauna composition. It is also questioned whether increased biodeposition of organic matter by the farmed scallops may affect the benthic environment. We will present results from; 1) an initial study carried out to determine how macro epi- and infauna in a pilot scale sea-ranching area (0.25 ha) was changed after a full seabed production cycle of five years, and 2) a monitoring program carried out at two full scale sea-ranching areas (10 ha) to investigate dynamics of mobile fauna with special emphasis on potential predators on scallops (crabs and sea stars).

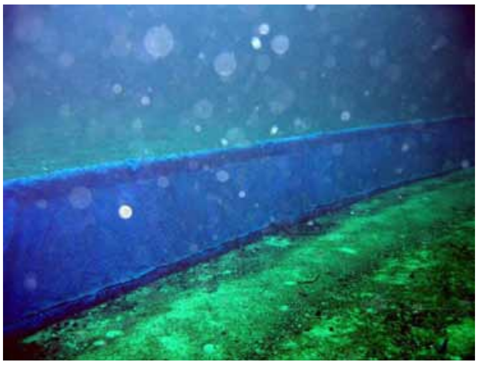

Figure 1. Fenced scallop sea-ranching site at Kvitsøy, Rogaland County, Norway.

KEYNOTE: Responsible approaches

36&37. PERSPECTIVES ON 'A RESPONSIBLE APPROACH TO MARINE STOCK ENHANCEMENT: AN UPDATE': BETTER INTEGRATION WITH FISHERY ASSESSMENT, MANAGEMENT, AND STAKEHOLDER INVOLVEMENT

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Marine fisheries enhancement is a set of management approaches involving the release of cultured organisms to enhance or restore fisheries. Such practices, including sea ranching, stock enhancement, and restocking, are widespread, of variable success, and often controversial. In principle, enhancements can help increase yield in fisheries, aid in conservation and rebuilding of depleted, threatened and endangered populations, provide partial mitigation for habitat loss and ecosystem effects of fishing, and help create new fisheries in restored habitats. Enhancements may afford economic and social benefits and incentives for active management and better governance. However, many enhancements have failed to deliver significant increases in yield or economic benefits or have contributed to management failure by encouraging or compensating for counterproductive changes in fishing practices or for habitat degradation. While some enhancement initiatives have been successful, only a few such 'success stories' have been documented in the scientific literature. It is constructive to ask why haven't enhancements made a greater contribution to fisheries. We believe there are several contributing factors. Success in fisheries management is measured against a broad set of criteria – biological, economic, social, and institutional attributes. Enhancements score well on some criteria, but only under certain situations delineated by ecological, economic and social conditions, by institutional arrangements that are well adapted to those conditions, and by adding value to other management measures. Thus, they need to be assessed, if not driven, from a fisheries management perspective, rather than the aquaculture production perspective that has been traditionally dominant.

Over the past two decades there has been a rapid increase in research and development of the science and tactics needed for enhancement to be effective. This is evidenced by the significant increase in peer-reviewed publications on restocking, stock enhancement and sea ranching research. Several key papers have had a strong influence on developing the science needed to realize effective enhancements. A set of principles aimed at promoting responsible development of restocking, stock enhancement, and sea ranching has gained widespread acceptance as a 'Responsible Approach'. Fisheries science and management, in general, and many aspects of fisheries enhancement have developed rapidly since the Responsible Approach was first formulated. We present an overview of our update to the Responsible Approach, which was written in light of these developments. The updated approach emphasizes the need for taking a broad and integrated view of the role of enhancements within fisheries management systems; using a stakeholder participatory and scientifically informed, accountable planning process; and assessing the potential contribution of enhancement and alternative or additional measures to fisheries management goals early on in the development or reform process. Progress in fisheries assessment methods applicable to enhancements and in fisheries governance provides the means for practical implementation of the updated approach.
KEY WORDS Stock enhancement, sea ranching, restocking, responsible approach, planning, fisheries assessment, population dynamics, modelling.

38. OPTIMIZING RELEASE STRATEGIES FOR BLUE CRABS IN CHESAPEAKE BAY

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The blue crab is both economically and ecologically important along the Atlantic and Gulf coasts of the United States. In Chesapeake Bay, the blue crab supports both a thriving recreational fishery and the region's most lucrative commercial fishery. Despite significant management efforts to reduce fishing pressure and improve habitat quality; however, blue crab populations declined sharply in the early 1990's and remained at an all-time low for more than a decade. Both the magnitude of the decline and the

persistence at low levels were unprecedented for the Chesapeake blue crab stock and in 2008, the National Oceanic and Atmospheric Administration designated the fishery as a federal disaster. In response, management agencies adopted coordinated conservation efforts have focused on protection for mature females. While abundance has rebounded in response to both conservation efforts and favorable environmental conditions, current evidence also indicates that in many regions of Chesapeake Bay nursery habitats are still well below carrying capacity. Thus, targeted restoration strategies such as restocking, may still be of considerable promise as complements to traditional fishery management approaches.

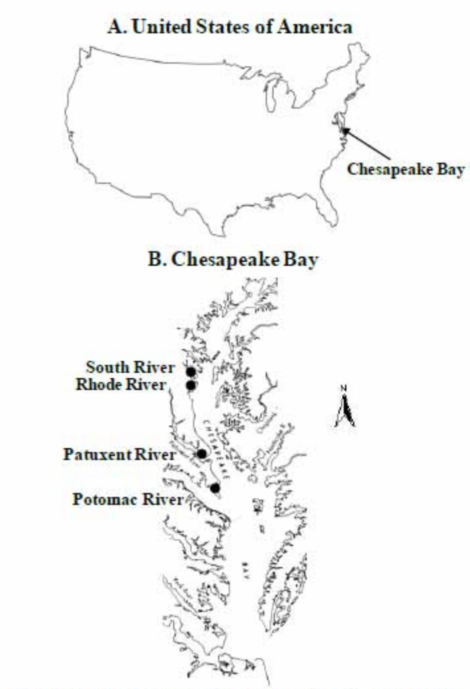

Figure 1. Locations of release sites in shallow nursery habitats of Chesapeake Bay

The feasibility of stock enhancement depends upon the ability of hatchery-reared juveniles to survive and grow in the natural environment. A critical step toward optimizing enhancement is to identify release strategies that maximize the performance of hatchery-reared individuals released into the field. Key considerations for optimizing the success of enhancement are (1) components of preparation and release (e.g., size-at-release, pre-release conditioning of hatchery-reared animals), (2) stocking variables (e.g., stocking density, season-of-release), (3) site selection and coordination (e.g., release locations, fishery exploitation). Herein, we present our analysis of a series comprehensive, integrated experimental and modeling approaches designed to predict the effectiveness of enhancement under varying release scenarios. Our rigorous comprehensive evaluation of release strategies is a key component of a responsible approach to fisheries enhancement and identifies release strategies that maximize the effectiveness of blue crab restocking efforts in Chesapeake Bay.

39. FINDING THE RIGHT STARTING POINTS IN STOCKED FISHERIES BY MODELING THE RIGHT END POINTS: EXPRESSING THE CARRYING CAPACITY AS A FUNCTION AND A DYNAMIC EQUILIBRIUM

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Modelling the growth and recruitment of fish populations often relies upon relationships which include a carrying capacity value. These relationships are used with great success in many fisheries models, but when the carrying capacity is needed to direct stocking densities however, current models become inadequate. When an attempt is made to link a static carrying capacity with an ecosystem-productivity model, it quickly becomes apparent that it is the *structure* of the population, and not its size, that determines the optimum stocking regimes. This is especially true in those fisheries where stock enhancement makes up a large proportion of recruitment, as the very structure of the population can be determined through stocking. Two models of the carrying capacity are demonstrated, which both express the carrying capacity as a function rather than a static value, and thus define the population structure of a stocked species. One of these models, which is based on the theory of energetic equivalence, is also used to examine the trade-off in a fishery between fish size and population density. The scope of this "*big fish or many fish*" trade-off is revealed as a simple power curve, bounded by the limits of asymptotic growth of a species, and shaped variously by metabolic scaling and density-dependence. The use of these models in matching release densities to ecosystem productivity, and in evaluating the outcomes of these stocking densities, are demonstrated using simulations, and with data from stocked Australian fisheries and manipulative tank experiments.

40. THE USE OF PLASTIC OVAL TAGS FOR MARK-RECAPTURE STUDIES OF JUVENILE JAPANESE FLOUNDER *Paralichthys olivaceus* ON THE NORTH-EAST COAST OF SHANDONG PROVINCE, CHINA

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As part of a stock enhancement research project in Shandong Province, China, plastic oval tags (POTs) were used to mark juvenile Japanese flounder, *Paralichthys olivaceus* (70-133mm total length). Optimal tag placement locations, retention, tagging rates and mortality were evaluated. Plastic oval tags were attached in an anterior direction of the caudal peduncle near the middle of dorsal fin and vertebra (location a) and near the middle of anal fin and vertebra (location b). Three days after tagging, both tag locations tested showed tag retention over 99%, and one-way ANOVA test showed no significant difference in POT retention between location a and b. Maximum tagging rates for tagging operations were 200-250 fish h^{-1} $operator^{-1}$ in 2009 and 300-350 fish h^{-1} $operator^{-1}$ in 2010, respectively. Moreover, tagging mortality ranged from 0.2% to 0.7% and there was no significant difference between the two years ($P > 0.05$). To study their migratory movements, recapture has been carried out in the coastal waters of Weihai City: 21,202 individuals in July 2009 at Beihai and 18,350 individuals in July 2010 at Lidao. The number of recaptured individuals from four recapture methods were 434 (2.05%) in 2009 and 619 (3.37%) in 2010. The predominantly northward dispersal of *P. olivaceus* from release site in 2010 was probably influenced by environmental conditions and food availability. However, a radiative moving from release site was observed in 2009. The longest mark-recapture duration was 496 days, with a distance up to 215 Km from release site in 2009. Mean speed of released fish was calculated as 0.46 Km day^{-1} in 2009 and 1.05 Km day^{-1} in 2010. Furthermore, depth profiles suggested all juveniles were captured in depths of 2-60m, and the tagged juveniles spent most of the first 3 months between 3-17 m on the edge of land (≤17 Km from the release site), which was followed by movements into 20-60 m depths. Patterns of movement showed a seasonal shift to deeper waters over time towards winter in both 2009 and 2010. These results indicated that the POTs for *P. olivaceus* were successfully developed and can be applied for stock enhancement research project, especially for long-term (>6 months) movement and behavioral studies.

41. OBAMA'S FLOUNDERING: POST-RELEASE ABILITIES, CHARACTERISTICS, AND ASSESSMENT OF CAGE CONDITIONED JAPANESE FLOUNDER, *PARALICHTHYS OLIVACEUS*

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Conditioning is the process of providing individuals reared for stock enhancement with some degree of "natural" experience prior to release. Conditioning flatfish before release may increase successful recruitment to the fishery, as fish trained for the "wild" may transition more easily and successfully upon release. Predator-free acclimation cages may help flatfish adjust to the wild environment, establish burial skills, begin pigment change, recover from transport stress, and experience natural (live) food sources before true release. Since 2008, Obama Station, National Center for Stock Enhancement, has conducted pre-release, experimental acclimation cage conditioning for Japanese flounder (N = 13 000 - 80 000) in both the Takahama and Obama portions of Wakasa Bay, Japan. Recaptured fish were acquired through a cooperative effort between researchers and local fishermen (both commercial and recreational). The overall objective was to describe how the characteristics of released flounder changed with acclimation cage exposure as well as to determine how recapture rates compared between conditioned and nonconditioned fish.

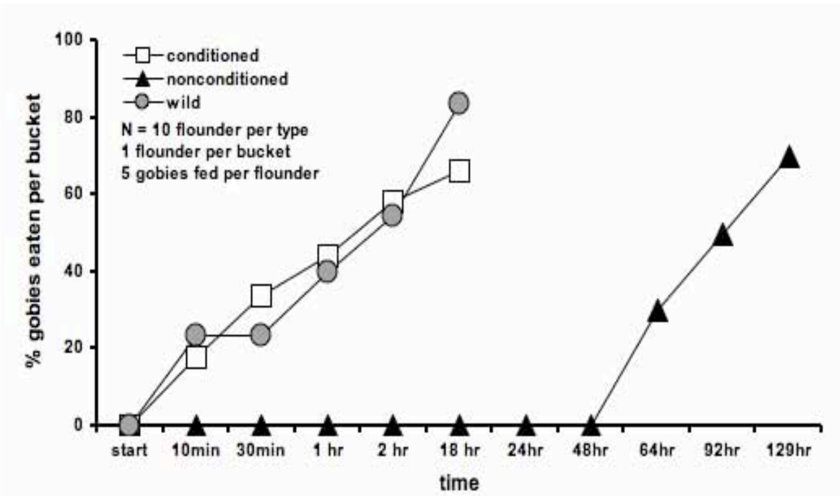

Figure 1. Percent of gobies (N=5 per bucket) eaten by flounder over time. Experimental trials were initiated on the day of release in 2010, with conditioned fish collected from the acclimation cages and nonconditioned fish taken directly from rearing tanks. Wild flounder were collected via set net within 3 days of experimental trials. Flounder were starved at least 24 hours before trials began. Note the logarithmic scale of the x-axis.

To date, more conditioned fish have been recaptured via fishermen's catch than non-conditioned fish. Within the first month of release, conditioned fish slightly led the advancement towards the mouth of the bays in 2008 (1-2 days) and 2010 (18 days), but movements were similar in 2009. Laboratory experiments revealed that conditioned fish exhibited enhanced burial abilities and begin feeding almost immediately, while non-conditioned fish took up to 2 full days before accepting live (goby) prey (Fig. 1). When subjected to adult Japanese flounder and crab predators, conditioned fish exhibited higher survival than non-conditioned fish. However, there was no difference in overall growth (determined by total body length and otolith measures) between conditioned and non-conditioned fish.

Initial observations suggest that non-feeding individuals recollected near the release sites (mostly non-conditioned fish) may be weaker and more likely to be caught by small boat beam trawl (towing speed 1 - 1.5 knots) than actively feeding, translocating fish. Thus, higher speed shrimp trawlers deeper in the bay (towing speed 3 - 3.5 knots) and set/fyke nets may be better, non-biased indicators of fitness and intermediate stocking success. These results show that acclimation cage conditioning can favorably alter the attributes of released fish. This work has powerful implications for Japanese flounder stocking strategies and may be applicable to other flatfish stocking efforts.

42. IMPLEMENTING A NEW STOCKING PROGRAM IN UNCHARTERED WATERS: DEVELOPING OPTIMAL RELEASE STRATEGIES FOR WINTER FLOUNDER IN MASSACHUSETTS AND NEW YORK, USA

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While winter flounder enhancement research has been ongoing in New Hampshire for more than a decade, only approximately 35,000 juveniles have been released in total. The goal of these past projects has not been to initiate large-scale releases. Rather, our "responsible approach" has been to develop the processes needed to successfully enhance winter flounder by answering key questions about optimal release strategies with small releases (<2,000 fish) in the event that large-scale stocking efforts occur. A new multi-state regional winter flounder stocking project has begun in Massachusetts and New York which will test these processes. The first part of this project is to formulate optimal release strategies; a comprehensive study currently is underway to do this in areas where little historic data exist using what we term "ecosystem analyses." For each region (East Hampton, NY and Martha's Vineyard, MA), two estuaries are being studied for a 12 month period to determine the spatial and temporal distribution of the wild winter flounder population, potential predators, and prey species, as well as other important parameters (water temperature, salinity, dissolved oxygen, substrate). These estuaries were chosen, in part, because historically winter flounder were abundant in them, and they appear to have appropriate habitat for juvenile winter flounder.

These "ecosystem analyses" will guide the decision-making process in determining the best site in each region for pilot-scale stockings of winter flounder. These sites will be areas with appropriate conditions for juvenile winter flounder. These areas also must be below carrying capacity; they must have excess resources to support additional fish – food availability exceeding wild winter flounder needs. The best season(s) and site(s) for releases will be the times and locations with low predator abundance yet high prey abundance. Optimal size-at-release for cultured winter flounder will be determined by the predator- prey complexes at the proposed release site during the proposed release season. Survival in fish increases with size; smaller fish typically have lower survival than larger individuals due to the wide range of predators capable of eating them. However, hatchery costs increase with fish size due to the increase in space, feed, and labor. The best size-at-release will be a compromise between these two conflicting demands. Knowing which predators are present (and what size flounder they can eat) will determine the most successful size-at-release for pilot-scale stockings. By using ecosystem analyses in unknown potential release sites, reasonable and responsible guidelines can be calculated for new stocking programs.

43. SITE FIDELITY AND MOVEMENT OF HATCHERY-REARED LINGCOD RELEASED INTO PUGET SOUND, WASHINGTON, USA

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Lingcod (*Ophiodon elongatus*) is a strongly piscivorous species that can exhibit strong site fidelity after recruiting to rocky reef habitats. Lingcod are highly-sought targets of recreational fishermen in Puget Sound, Washington, USA because of their large size and flesh quality. Population declines in lingcod and other species have prompted strong fishing restrictions in Puget Sound and beyond. The release of hatchery-reared lingcod may be a viable means to bolster the wild population. However, development of a stock enhancement program requires a cautious approach that includes releasing small numbers of fish and monitoring their impacts on natural lingcod and other imperiled species.

A Before-After-Control-Impact (BACI) experimental design is planned to quantify the potential costs and benefits of lingcod stock enhancement. Hatchery lingcod will be released at two sites in Puget Sound. To determine the impacts of releases on wild fishes, the abundance and diversity of wild fishes will be monitored at the two release sites, and compared to two control sites where no hatchery lingcod are present. Conducting a valid BACI experiment requires distinct "control" sites with no hatchery-released fish present and "impact" sites with hatchery-released fish present. However it may be difficult to create "impact" sites if released lingcod quickly disperse away from impact sites or to control sites.

To determine the optimal release conditions that would maximize site fidelity, hatchery-reared lingcod were released at different ages, seasons, and habitats. To avoid contamination of future control sites, less than 150 lingcod were released, but each was implanted with an acoustic telemetry tag. A tag-effects study indicated that the telemetry tags do not affect movement behavior. Mobile tracking was conducted to quantify site fidelity and movements away from the release site. The poorest site fidelity was observed in the two youngest release groups (approximately 9 and 11 months post-hatch; Figure 1). Approximately one year after release, 4% and 4% of these two subyearling release groups were detected within three-km of the release site while 17% and 16% were detected further away. Seventeen-month-old lingcod that were released in the summer showed the best site fidelity, with 23% remaining within three-km of the release site one year after release. None of the 17-month-old lingcod were detected further away while mobile tracking approximately one year after release, suggesting that this release age and season may be best suited for the future BACI experiment. We will describe movement patterns of individual fish to provide some insights into the behavioral mechanisms that may cause subyearling and yearling lingcod to differ in distributions one year after release, and also compare these release groups to four-year-old lingcod released at similar sites. Hatchery lingcod behavior will be compared to published studies on wild lingcod behavior.

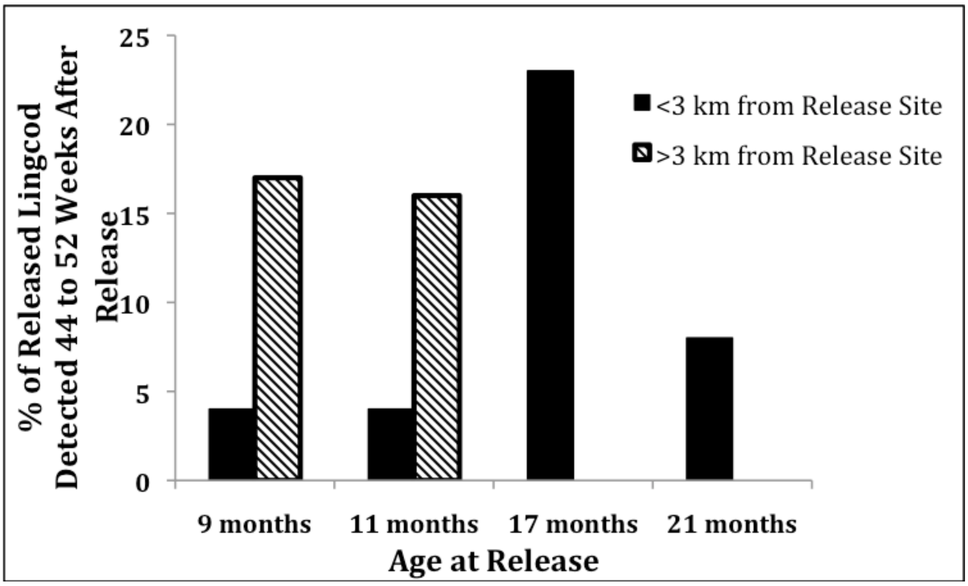

Figure 1: Movement of hatchery-reared lingcod varied as a function of age at release. The two youngest release groups dispersed from the release site and were more likely to be detected more than three km from the release site than less than three km from the release site. The two oldest release groups displayed the opposite pattern. Mobile tracking was conducted within three km of the release site 52 weeks after release, and at distances greater than three km of the release site 44 weeks after release.

44. SHELTER ACCLIMATION DECREASES THE POST-RELEASE PREDATION MORTALITY OF HATCHERY-REARED BLACK-SPOT TUSKFISH *CHOERODON SCHOENLEINII*

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Black-spot tuskfish *Choerodon schoenleinii* is a highly prized commercial fish in many areas of Asia, including Japan, Hong Kong and Malaysia. In Okinawa Prefecture, Japan, the black-spot tuskfish has been targeted for stock enhancement since 2000, due to its low total catch in the last decade. Around the coasts of Ishigaki Island in Okinawa Prefecture, hatchery-reared fish of 50–100 mm total length (TL) were experimentally released onto dead coral patches because the fish at least over 90 mm TL utilizes a burrow-like shelter which it excavates at the base of hard substrates, such as dead corals, for predator avoidance. However, some released fish were found in the stomachs of large piscivores and all released fish disappeared from the release site within 2 weeks (Okuzawa et al., unpubl. data, 2009). Post-release predation mortality is a plausible cause for this rapid disappearance; therefore, developing release strategies that reduce post-release predation mortality is a priority for ensuring the success of the stock enhancement of this species.

In this study, we investigated the effect of pre-release shelter acclimation whether it enhances the shelter utilization by tuskfish and consequently decreases the post-release predation mortality. We first performed laboratory experiments to investigate whether acclimation to shelters affects the post-release survival of hatchery-reared black-spot tuskfish in the presence of a reef resident predator, the white-streaked grouper

Epinephelus ongus. Tuskfish juveniles were exposed to groupers under three different experimental conditions/treatments: (1) acclimation of fish to shelters prior to their exposure to groupers; (2) no acclimation of fish to shelters, but with shelters available during their exposure to groupers; (3) fish not acclimated to shelters and no shelters available during their exposure to groupers. Tuskfish that were acclimated to shelters utilized shelters more frequently than did non-acclimated fish, and the survival rate of acclimated fish was higher than those of fish in the other treatments.

We then conducted field experiments using acoustic telemetry. We acclimated four tuskfish juveniles to shelters in cages before release, and monitored their movements with six non-acclimated fish. While 67% of the non-acclimated fish showed untypical movements before cease of the detections that suggest the predation event occurred, none of the acclimated fish showed the untypical movements. Based on the detection pattern, survival rate one month after release was estimated. None (0 %), two (50 %) and two (50 %) of the acclimated fish were estimated as preyed, survived and un-known, respectively, while, four (67 %), none (0 %) and two (23 %) of the non-acclimated fish were estimated as preyed, survived and unknown, respectively.

These results suggest that the shelter acclimation decreases the post-release predation mortality of hatchery-reared black-spot tuskfish. Since many sedentary juveniles utilize shelters for predator avoidance, this acclimation approach might be useful for mitigating the post-release predation mortality of the other shelter-dwelling species for stock enhancement.

45. DETERMINING OPTIMAL RELEASE HABITAT FOR BLACK ROCKFISH: EXAMINING GROWTH RATE, FEEDING CONDITION AND RECAPTURE RATE

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The black rockfish, *Sebastes schlegelii*, is a viviparous inhabitant of shallow coastal waters (<100 m deep) in Korea, Japan and northern China. This species comprises one of the most commercially important Sebastes coastal fisheries in these eastern Asian countries and appears to be an appropriate model for studying stock enhancement strategies because of key biological traits such as rapid growth and limited migration. In this study, field surveys (wild fish ecology and release-recapture trials) were conducted to assess the efficiency of stocking based on the ecological characteristics of this species. To assess the suitability of variable environments as nursery grounds for black rockfish juveniles, growth rate and feeding condition of wild juveniles were examined in two nursery sites, Akamae (Stn. 1) and Hanoki (Stn. 2), from 2004 to 2006. Stn. 1 is characterized by brackish mud/sand sediment with sea grass vegetation and Stn. 2 by thick sea grass beds. Growth rate of wild juveniles was higher at Stn. 1 relative to Stn. 2. Stomach contents of juveniles at Stn. 1 were comprised mainly of mysids and large gammarids, *Ampithoe* spp., while juveniles at Stn. 2 foraged mainly on small gammarids. The abundance of mysids and large gammarids present at Stn. 1 supported the high growth rate of juveniles.

In addition, experimental releases were conducted to examine the recapture potential of each habitat. Small size hatchery fishes (40 mm in TL) were released at Stn. 2 in 2004 and 2005, at Stn. 1 in 2006 and 2007, and at Shirahama (Stn. 3) every year (2004 to 2007). Stn. 3 was located in the middle part of the bay where large sizes (100mm in TL) hatchery fish were released from 1999. As of June 2010, the recapture rate (market return rate) of hatchery fish released at Stn. 1 was 5.0% in the 2006 group and 8.0% in the 2007 group. Return rate of fish released at Stn. 3 ranged from 0.8 to 2.9% (2004-2007) while those at Stn. 2 were 3.0% (2004) and 1.1 % (2005). Landings of black rockfish at the Miyako Fish Market have increased approximately 2.5 times after the onset of stockings from 1999. The efficiency (economic return rate; market sales/hatchery costs) of hatchery fish released at Stn. 1 was estimated to be 1.25, which is comparable to that of fish released at Stn. 3 at a size of 95 mm TL (0.98). We conclude that habitats with an abundance of mysids and large gammarids bear higher potential as successful nursery grounds for black rockfish because growth rate and food quality in these areas. The higher return rates and economic return rate for fish released at Stn. 1 also supports the notion that these brackish shallow habitats constitute the most appropriate release site for black rockfish. These results indicated the possibility of reducing size at release to less than half, which implies a strong reduction of hatchery costs if juveniles are released in appropriate sites and may also have implications for the stocking strategy of other *Sebastes* species.

THEME F: Enhanced knowledge on populations and ecosystems from releases of cultured animals

46. GROWTH, SURVIVAL AND REPRODUCTION OF SANDFISH *HOLOTHURIA SCABRA* RELEASED IN A PILOT SEA RANCH IN THE PHILIPPINES

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Communal sandfish sea ranching was piloted in the Philippines to evaluate its viability as a source of supplemental income for small fishermen and help rebuild the spawning population of *Holothuria scabra* which one of the high-value sea cucumber species. Multiple batches (n= 10) of cultured sandfish (> 3 g) were released in a 5-hectare pilot sea cucumber sea ranch located in the seagrass area in Victory, Bolinao Pangasinan over a 16-month period starting from December 2007. All juveniles (n= 16,117) were tagged with flourochrome dyes and released in a 2,200 m^{-2} core release zone at the center of the sea ranch. Sandfish were sampled every 3-4 months over 26 months using belt transects to determine densities in different zones and size structure (length and weight), to estimate growth and survival. At the same time, the growth and survival of a single batch of juveniles released in three circular 100 m^{-2} pens (n = 200 ind pen^{-1}) in the sea ranch were monitored by retrieving and measuring all surviving animals in each pen during each monitoring period.

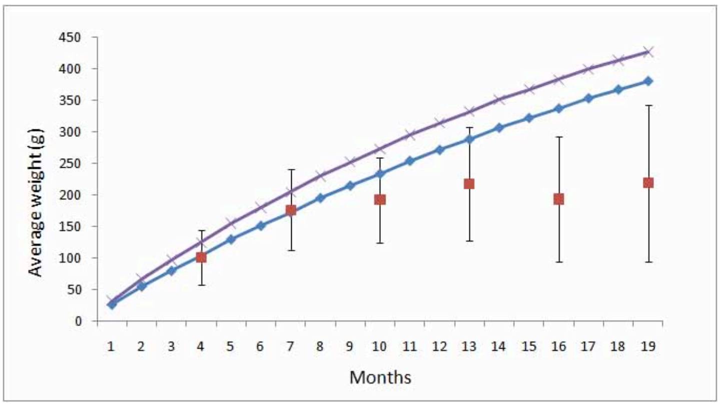

Figure 1. Estimated VBGF curve derived from weight frequency (ELEFAN) distribution in the sea ranching area (Woo = 697.2 g, K = 0.60) and ; pens (Woo = 735.15g, K = 0.46).

Released juveniles were found only within the core release zone after four months, however, by the seventh month, many juveniles have moved to the outer reserve area, over 150 m away from release area. During this time, the maximum estimated density and biomass in the sea ranch were only 0.06 ind m^{-2} and 5.4 g m^{-2} respectively. Over the next months, density decreased progressively from the core release zone to the peripheral areas including the adjacent area outside the sea ranch. Distribution was very heterogeneous with densities consistently lowest in the southern portion of the sea ranch which has coarser substrate and lower sediment stability. These validate previous studies indicating active substrate or microhabitat selection by sandfish.

The estimated survival rate in the sea ranch varied widely during each sampling period (14- 44%) in part confounded by the timing of the juvenile releases and the low retrieval rates of smaller animals (< 40 g). Modal weight progression was fastest during the first seven months reaching a modal size of 160-199 g. The growth curves based on the estimated von Bertalanffy growth frequency (VBGF) over a 19-month period is shown in Figure 1. In the pens, average survival rate was 29 % (± 3) over the same period. Average total weight increment was also fastest during the first seven months (~25 g month $^{-1}$) and leveled off at an average size of about 200 g after 10 months (Fig. 1). Total biomass ranged from 84–200 g m^{-2} in the pens suggesting that growth may have in part been affected by density dependent factors. Sharp decreases in the modal sizes after typhoons indicate that sandfish are sensitive to decreases in salinity and strong wave action. Recovery was fast after a storm in May 2009 which deposited a lot of suspended fine sediment and organic matter into the sea ranch. However, longer-term changes in the quality of sediment and grazing area after consecutive storms and protracted heavy rainfall in September-October 2009, resulted in a progressive decrease in the estimated total biomass of about 65% and 15% in estimated abundance within 5 months.

Notably, 31% of the sampled sandfish have reached size at sexual maturity (> 200 g) after only 7 months. Local managers observed sandfish in the sea ranch exhibiting the typical spawning posture and behavior on several occasions and during different times of the day. The estimated density of sexually mature animals in the sea ranch was 100 ind ha^{-1} by the seventh month, and reached up to 590 ind ha^{-1}after a year and half. These demonstrate that a critical spawning population can be established in a suitable and well-managed sea ranch area in less than a year. Moreover, synchronized mass spawning at midday was documented in 23 February 2010 wherein 19.7% of the sandfish observed released gametes. In addition, spicule analysis revealed wild recruits (i.e. without flourochrome stains) in the sea ranch. Whether larval settlement and benthic recruitment are enhanced by the high density of adults in the sea ranch remains to be investigated.

Results of this study provide valuable insights in optimizing the ecological impacts of sandfish sea ranching. Multiple small batch releases and periodic selective harvests of animals > 320 g (minimum export grade size) and regular monitoring in community-managed sea ranch are good management practices. These promote genetic diversity conservation, maintenance of effective spawning biomass, increased fertilization success and larval supply that can contribute to the replenishment of the wild population. The pilot communal sea ranch has become a demonstration and learning site for effective area management within an integrated fishery management framework to restore depleted stocks and provide incentives for community participation in resources management.

47. DOES STOCKING AUSTRALIAN NATIVE PREDATORY FISH PROVIDE A CONTROL OPTION FOR INVASIVE EUROPEAN CARP (*CYPRINUS CARPIO*)?

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Stocking activities support a number of vital objectives in fisheries management, including native fish enhancement, improved water quality (biomanipulation), recreational fishing and biological control. We examined the potential for stock enhancement of Australian native fish to control invasive European carp (*Cyprinus carpio*) through predation. We selected two factors for quantification that may influence predation rates on carp; prey size and relative abundance, and the habitat type in which a predator forages. In tank trials, Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*) and Australian bass (*Macquaria novemaculeata*) had no significant preference for any particular species offered. When offered a carp of varying sizes, golden perch and Australian bass consumed the smallest carp available, whereas Murray cod showed no size preference. In Australian rivers, adult carp select inundated macrophytes in shallow, peripheral marginal habitats that are relatively free from predators to spawn. Juvenile carp therefore have the opportunity to grow rapidly in these habitats and soon reach a size that is free from predation by gape-limited predators. Predators with a preference for smaller carp may not have any impact on reducing carp populations. In mesocosm trials, Murray cod prey preferences were altered by the available habitat type, but there were still no strong preferences for carp when native prey were available. These results suggest that foraging activities and predation rates in aquatic systems are influenced by particular combinations of abiotic factors, such as habitat type and complexity, and biotic factors such as prey size and food availability. Evaluation of prey preferences under varying conditions is crucial prior to stocking predators for biological control to avoid potentially devastating and irreversible impacts on non-target species.

48. THE FIRST CATFISH, *Pseudoplatystoma corruscans*, RESTOCKING PROGRAM IN THE SÃO FRANCISCO RIVER BASIN: ANALYZING THE REPRESENTATIVENESS OF ITS FOUNDER STOCK

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The catfish, *Pseudoplatystoma corruscans* (Figure 1), is found in the South American river basins, being considered the most important predator in the São Francisco River, where it performs upstream migration for spawning. Catches of this species have been reduced to virtually zero. Overfishing and hydroelectric dam construction, which fragment the river system hampering upstream migration and delimiting reproduction areas are possible causes of endangering fish populations. These factors are emphasizing the need to invest in restocking programs as an attempt to restore the fish genetic diversity in the river system. The objective of this study was to estimate the genetic diversity as related to wild populations and relatedness of the founder stock of the first *P. corruscans* restocking program by microsatellite markers, in order to ensure maximum genetic diversity in the offspring and contribute to a more efficient design of genetically sustainable restocking programs.

Figure 1- *Pseudoplatystoma corruscans*

Ninety-nine individuals from four different locations, including the middle, lower-middle and lower San Francisco river basin comprised the founder stock of *P. corruscans* to be used in the restocking program. Caudal fin tissue samples from 80 individuals randomly collected in a subset of the founder stock were used to extract DNA. Genetic variability was evaluated through the screening of six microsatellite loci (Pcor01, Pcor02, Pcor05, Pcor10, Pcor21 and Pcor 28), previously described by Revaldaves *et al.* (2005) and Pereira et al (2008). Number of alleles (A), observed (H_o) and expected (H_e) heterozygosities and deviation from the Hardy–Weinberg equilibrium (HWE) were calculated as estimators of genetic diversity by using GENEPOP software. Inbreeding coefficient (F_{IS}) was calculated using arlequinVer. 2.000. Effective number of alleles per locus (A_e) and pairwise relatedness coefficient (r_{xy}) of Ritland (1996) were obtained using the GenAlEx 6.1.

Genetic variability of the catfish founder stock for the six microsatellite loci is summarized in Table 1. A total of 48 alleles were detected for the set of markers and the average number of alleles were 8, ranging from a fixed allele (Pcor 28) to 12 (Pcor 10). Observed and expected heterozygosities ranged from 0 (Pcor 28) to 0.711 (Pcor 10), and from 0 (Pcor 28) to 0.856 (Pcor 2), respectively. Except for Pcor 28, which showed a fixed allele, H_o was always lower than H_e, indicating a heterozygote deficit. Chi-square test indicated significant deviations ($P < 0.001$) from the Hardy-Weinberg equilibrium at these five loci. Likewise, inbreeding coefficient (F_{IS}) suggested a heterozygote deficit, ranging from 0.146 (Pcor 10) to 1 (Pcor 28), with a mean value of 0.222 ± 0.061. Based on the genetic relatedness coefficient (r_{xy}), a total of 2,926 pairwise combinations were generated with a mean value of -0.008.
In our study, the average number of alleles found for the six microsatellite loci was 9.4. Pereira et al. (2009) found an average of 15.28 alleles for seven microsatellite markers, including the same set of six markers we used in 6 populations of 223 individuals sampled in Paraná-Paraguay River basins. São Francisco River in wild populations from the upper and middle stretches showed an average of 7.8 alleles (data not shown). The deficiency in heterozygotes reflected deviations from Hardy-Weinberg equilibrium, evidenced by the significant difference (P<0.001) for five loci examined (except for Pcor 28). Possibly, this deficit was caused by the Wahlund effect, which always occurs when two or more populations are gathered in samples. As the founder stock was constructed with fish from different stretches of the river, gametes containing alleles from the middle São Francisco would not have chance to meet gametes from the lower or submiddle, preventing the formation of individuals with both alleles and thus generating $H_o < H_e$. Most of the pairwise combinations (62.37%) showed no relatedness with r_{xy} coefficients ≤ 0. Using the 0.07 value as the threshold for the existence of parentage (Sriphairoj et al, 2007), the percentage of unrelated pairwise combinations rise to 84.42%. Considering that the average number of alleles is compatible to those of wild populations of this river and that the majority of breeders showed no genetic relatedness, this founder stock will enable hatcheries to keep fish with rare alleles, hence maximizing genetic diversity and reducing inbreeding.

Table 1. Genetic variability of the *Pseudoplatystoma corruscans* founder stock

	Pcor1	Pcor2	Pcor5	Pcor10	Pcor21	Mean
Number of samples	76	73	76	76	77	75.6±1.36
A^1	6	11	9	12	9	9.4 ± 2.06
N_a^2	3.28	6.66	3.32	5.72	5.25	4.85±1.34
H_o^1	0.566	0.589	0.513	0.711	0.662	0.608±0.070
H_e^1	0.699	0.856	0.704	0.831	0.815	0.781±0.066
F_{IS}^3 (P-value)	0.192 (0.00684)	0.313 (0.00000)	0.272 (0.00000)	0.146 (0.00293)	0.188 (0.00098)	0.222±0.061 (0.00215)
HWE^1	***	***	***	***	***	

A = number of alleles; N_a = effective number of alleles, H_o = heterozygosity observed, H_e = heterozygosity expected; F_{IS}: inbreeding coefficient; Sources: [1] Genepop; [2] GenAlEx 6.1; [3] Arlequin; HWE = Hardy-Weinberg Equilibrium, ns = not significant, *** P <0.001.

49. EARLY DEVELOPMENT OF SESSILE AND EPIFAUNAL COMMUNITY ON A CREATED INTERTIDAL OYSTER *CRASSOSTREA ARIAKENSIS* REEF IN THE YANGTZE RIVER ESTUARY, CHINA

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Oyster reef habitats are increasingly restored along the Atlantic coast of USA and Yangtze River estuary of China as coastal ecosystems may be vulnerable to collapse in the near future due to human disturbance such as over-fishing, pollution, degradation of water quality and anthropogenic climate change. These restoration programs were droved by fishery stock enhancement (establishment of oyster population at self-sustaining levels) in early stage. Recent emphasis has shift to restore the ecosystem services that natural oyster reefs provide. Although oyster reef is increasing restored for fishery or ecological goals, little efforts were done to describe reef-associated community of resident benthic organisms and the effects of living oyster population on reef-associated community metrics. The present study examined the development of oyster *Crassostrea ariakensis* population and its associated community of resident benthic organisms on a created intertidal reef in the Yangtze River estuary, and analyzed the correlation between reef inhabitants and oyster metrics. By 3 years after restoration, sustainable oyster populations were well established on the created reef. The market-size oysters (>70 mm SH) make up more than 20% of total oysters and have mean abundances of 95-225 ind./m^2. Community metrics (species number, abundance and biomass) of total benthic organisms and each taxonomic group (crustaceans, mollusks and annelids) on created reef showed generally increasing trends with reef development. The barnacle (*Balanus albicostatus*) abundances and biomass were significantly and conversely correlated with oyster metrics. It is absent of evident associations among total community descriptors and oyster metrics. In contrast to molluscans, crustaceans were more frequently and positively correlated with oyster abundances and biomass. All but one among annelids and oyster population

were significant and positive correlation. It was concluded that oyster abundances appeared to be strong predictors for barnacles, crustaceans and annelids rather than total abundances and diversity of resident benthic organisms.

THEME G: Adapting to change: climate, habitat and socio-economics

50. SUSTAINABLE FISHERIES MANAGEMENT OF PACIFIC SALMON UNDER THE WARMING CLIMATE

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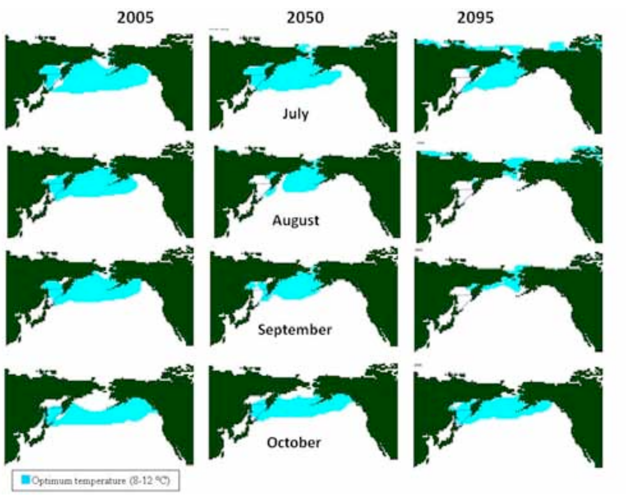
At the present, the global warming has positively affected for increase growth at age-1 and survival of Hokkaido chum salmon. In the future, however, this global warming will affect decrease in carrying capacity and distribution area of chum salmon in the North Pacific Ocean. For establishing the sustainability on seafood security and ocean ecosystem conservation, we have 3 questions. 1) How can we use the ocean organisms as -seafood in the future? 2) What do we need for seafood security and ocean ecosystem sustainability in present and future? 3) How do we establish the sustainable fisheries management based on the ecosystem approach? In order to answer these issues, we should know carrying capacity are limited and fluctuated in ocean ecosystem, that fisheries industry are emphasized not only the economic efficiency, but also the ecosystem approach. As the education, we need paradigm shift from the traditional fisheries science for only fisheries to the ecological fisheries science for the protection of marine ecosystems and human food resources in order to be human well-being in future generation. Adaptive management and precautionary principle are essentially important to establish the sustainable fisheries management based on the ecosystem approach.



51. MEASURING THE EFFECT OF SOCIOECONOMIC FACTORS ON CONSUMER PREFERENCES FOR SEAFOOD –A CASE STUDY IN HAWAII

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The US currently ranks third behind China and Japan in seafood consumption and 84 percent of the seafood supply is imported from foreign sources, over half of which is farm-raised. As the structure of seafood production includes increasingly more aquaculture, much research has focused on production economics in the industry. Fewer studies have investigated the consumer side of the spectrum and the economics of changing seafood markets. Socioeconomic factors often affect the adaptability to changing markets and consumer preferences. Using conjoint analysis, this study aims to measure the effect of socioeconomic factors such as income, ethnicity and age on consumer preferences for seafood in Hawaii. A survey of Hawaii consumers examined the willingness to pay for seafood attributes (i.e. fresh vs. frozen, farm-raised vs. wild-caught) across different fish species. The results will identify seafood market segments across demographics, information which is useful for producers, retailers, and also for policy recommendations in marine aquaculture. Knowing consumer willingness (not) to pay for certain types of fish attributes and how the consumer preferences change according to the changes of socioeconomic factors will help improve the ability of producers/suppliers to better market their products. Policy makers could also use findings of this study to guide effective legislation related to fishery development and management, i.e. to set the direction for marine aquaculture development, and to facilitate and promote the aquaculture and seafood industry.

52. CURRENT HATCHERY PROGRAMS AND FUTURE STOCK MANAGEMENT OF CHUM SALMON IN HOKKAIDO, NORTHERN JAPAN

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Since the late 20th century, the biomass of Pacific salmon in the North Pacific has increased and recent biomass is at a historically high level. Japanese chum salmon *Oncorhynchus keta* has contributed to the increase of salmon biomass; 61-72% of total commercial chum salmon catches in the North Pacific in 2003-2007 (NPAFC, http://www.npafc.org/new/index.html).

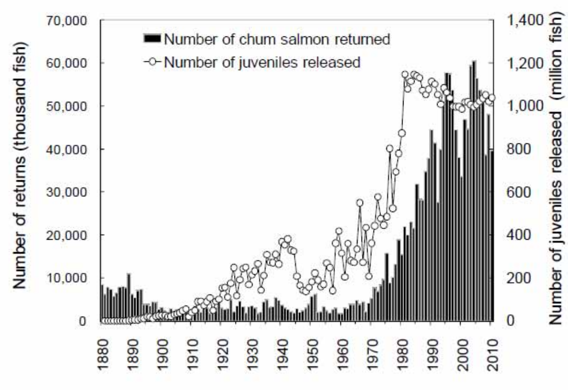

Fig 1 Number of chum salmon released and returned in Hokkaido, 1880-2010.

Hokkaido, northern Japan, is the principal area of salmon production in Japan. To support commercial chum salmon fisheries, a hatchery stock enhancement program began in the 1880s and has been conducted for over

120 years. The number of chum salmon returning to Hokkaido rapidly increased during the last quarter of the 20th century and has ranged from 33.5 to 60.5 million fish in the last 10 years. Recent high returns have been attributed mainly to the successful hatchery programs (Kaeriyama 1999), favourable oceanic conditions, and closure of high-seas fisheries (Morita et al. 2006).

The number of hatchery-reared chum salmon released in Hokkaido peaked in the 1980s, and thereafter, by reducing ineffective stocking; the annual number is recently ~one billion fish (Fig. 1). For the current hatchery programs, as many as 1.27 million spawners are taken for broodstock and used for artificial fertilization. Although such intensive hatchery programs have been conducted over more than 20 generations, Beacham et al. (2008) found no evidence that Japanese chum salmon populations have lower genetic diversity than populations from Russia and North America. The recent return rates of Hokkaido chum salmon have demonstrated no declining trend although inter-annual fluctuation has been observed and the fluctuation pattern in return rates differed among regions within Hokkaido.

Thus, at present, the hatchery program of chum salmon in Hokkaido is successful for the purpose of increasing commercial catches, even if factors other than improvement of hatchery techniques have contributed to the recent high returns. Large numbers of hatchery fish are a dominant feature of chum salmon management in Japan and will likely remain so in the future. However, if the management of salmon is to succeed over the long-term it is important that self-sustaining populations and healthy spawning habitats persist (Mobrand et al. 2005). Unfortunately, information on naturally spawning chum salmon in Hokkaido is scarce, and therefore, assessment for naturally spawning populations commenced in 2008. Monitoring both hatchery- and natural-origin chum salmon is important and a novel strategy to properly manage chum salmon populations in Japan should be modelled and conducted.

53. MARINE STOCK ENHANCEMENTS UNDER A CHANGING CLIMATE: IMPLICATIONS FOR THE RESPONSIBLE ENHANCEMENT APPROACH

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Marine stock enhancements refer to a suite of management actions intended to restore, conserve or enhance fisheries through the release of cultured organisms. The need to develop, evaluate and manage enhancements from a broad, integrated fisheries management perspective, which reflects the rapidly changing fisheries science and management contexts in which enhancements take place, is now widely accepted and well embedded in the revised 'Responsible Approach' (Lorenzen et al. 2010). Climate change represents one of many existing stresses on marine systems, others being overfishing, pollution and habitat degradation. However, in combination with other stressors, climate change threatens to push marine social-ecological systems beyond their historical ranges of variability, creating a complex and unpredictable mix of challenges (Perry et al. 2010) for marine resource users and managers. In this paper, an interdisciplinary team evaluates the revised Responsible Approach through a climate change lens. In particular, we assess the adequacy of the approach in the face of some of the key challenges presented by climate change, including increased variability and uncertainty, and a greater incidence of ecosystem surprises and range shifts. We highlight a number of issues related to marine ecology, fisheries biology and management, sociology, economics and governance that are likely to challenge practitioners involved in the development, evaluation and management of marine stock enhancements, and suggest further revisions to the Responsible Approach. We conclude by highlighting the need to consider the role of stock and habitat enhancements when assessing the vulnerability of marine systems to climate change, and in the design of regional fisheries climate change adaptation plans.

Lorenzen, K., Leber, K. M. and Blankenship, H. L. Responsible Approach to Marine Stock Enhancement: An Update. *Reviews in Fisheries Science,* 18(2):189-210 (2010).

Perry, R. I., Omner, R. E., Barabge M. and Werner, F.. The challenge of adapting marine social-ecological systems to the additional stress of climate change. *Current Opinion in Environmental Sustainability, 2:356-363 (2010).*

Keywords: climate change, stock enhancement, responsible enhancement approach

54. SUMMARY/DISCUSSION

List of Posters

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