# YELLOWTAIL FLOUNDER TAGGING STUDY

A Proposal to the Northeast Consortium Cooperative Research (FY2003)
by
the Northeast Fisheries Science Center and New England Fishermen
March 30, 2005

**Abstract**
New England fishermen and the Northeast Fisheries Science Center request a grant of $200,000 from the Northeast Consortium to expand and improve an ongoing tagging study for yellowtail flounder in Northeast U.S. waters. The proposal is designed to charter commercial fishing vessels to tag yellowtail flounder with conventional disc tags and data-storage tags on Georges Bank and the Cape Cod-Gulf of Maine fishing grounds with the objective of estimating movement among stocks areas and mortality within stock areas as well as providing growth observations. Currently funded tagging efforts are planned to tag yellowtail from the Gulf of Maine to the Mid Atlantic. However, despite considerable uncertainties in the Cape Cod yellowtail and Georges Bank yellowtail stock assessments, and the need for independent information on movement, mortality and growth, the current allocation of tagging efforts are disproportionately low for the Georges Bank and Cape Cod areas. Therefore, statistical estimation will be improved by increasing the number of tags released on Georges Bank and off Cape Cod. This proposal is designed to complement concurrent studies with a common tagging protocol, a single experimental and analytical design, the same tag return system as well as coordinated outreach efforts. Through the cooperation of industry leaders and fishery scientists, the proposal was designed to reduce uncertainty in yellowtail flounder stock assessments, thereby improving fishery management.

Table of Contents

Rationale…… 2
Review of Previous Work…….. 5
Project Organization and Scientific Hypothesis…… 10
Project Plan and Experimental Design…….. 10
Available Resources…….. 14
Dissemination of Results, Impacts and Deliverables……..…….. 15
Supplemental Information
- Literature Cited……. i
- Budget and Budget Justification……... iii
- Resumes…… v
- Description of Prior Results…….. xviii
- Current and Pending Support for Principal Investigators……. xix
- Appendix A. Tagging Protocol……. xxi
- Appendix B. Cooperative-Tagging.org……. xxiii
- Appendix C. Budget Worksheet…… xxiv

**Rationale**

Yellowtail flounder is one of the principal resources of the northeast groundfish complex, with major fishing grounds on Georges Bank, off southern New England and off Cape Cod (Figure 1). The fishery is among the most productive and valuable New England fish species, yielding 16 million lb and $15 million in 2001 to U.S. fishermen (NMFS 2002). However, with all three stocks currently rebuilding from an overfished condition, the potential yield of yellowtail is much greater than the current yield (the estimated maximum sustainable yield from the three New England stocks is 65 million lb; NEFSC 2002, 2003).

Managing the recovery of yellowtail resources and maintaining optimum yield require precise stock assessments and accurate forecasts of the population and fishery. Although yellowtail flounder stock assessments have provided valuable information for fishery management advice, several sources of uncertainty persist. This proposal was developed to provide information on U.S. yellowtail resources that will complement the current programmatic data collection and analytical methods to reduce uncertainty in stock assessment and management advice.

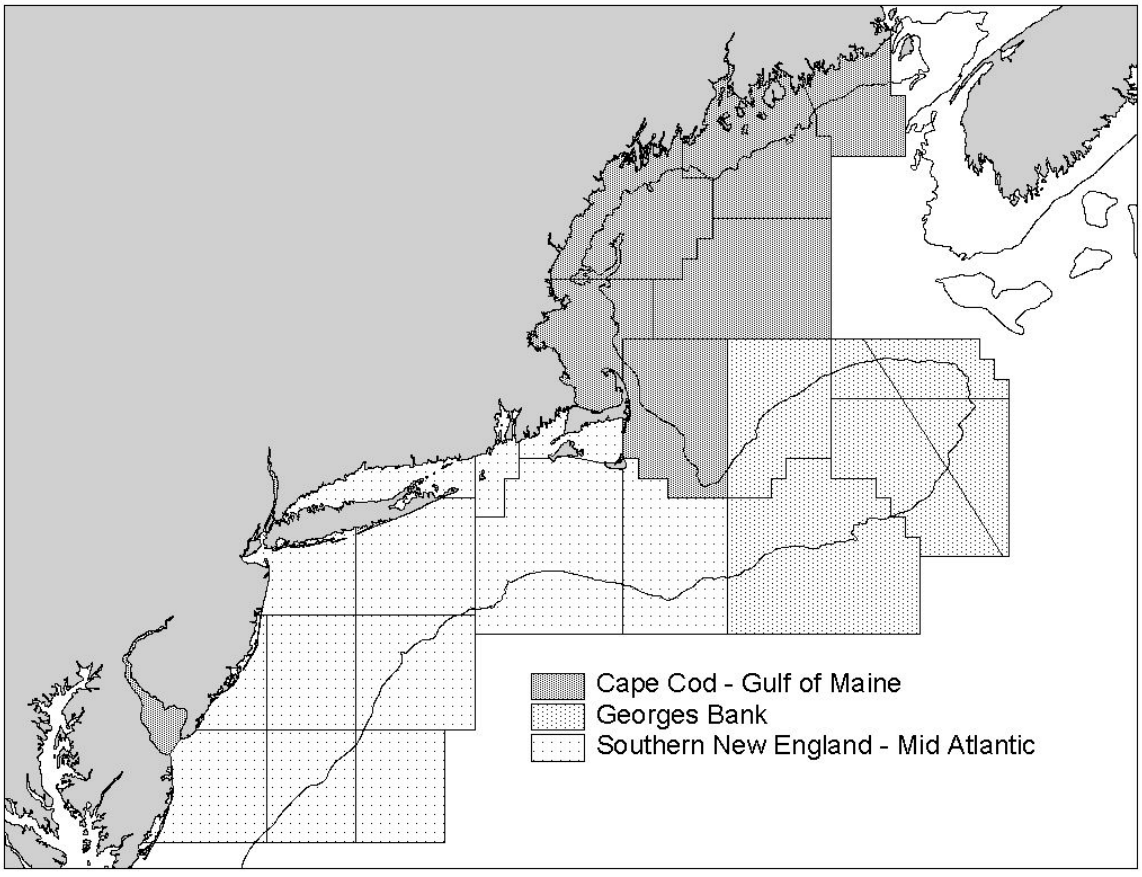


**Figure 1. Yellowtail flounder management areas off the northeastern U.S.**

Assessments of all three New England yellowtail stocks tend to overestimate stock size and underestimate fishing mortality, leading to considerable uncertainty in catch forecasts. The source of this apparent bias is not well known, but may result from movement among stock areas, insufficient sampling of areas closed to fishing, inaccurate age determinations, misrepresentative sampling of distributional patterns, underreported catch, or inaccurate assumptions about natural mortality (NEFSC 2002, 2003; TRAC 2003).

The Georges Bank yellowtail flounder stock has demonstrated a remarkable rebuilding capacity. Management actions effectively reduced fishing mortality on the Bank since 1995, and the population responded with substantial and steady increases in biomass. The year-round closure of a large portion of the Bank to U.S. fishing (closed area II, Figure 2) and conservative Canadian catch limits successfully limited harvests and allowed the stock to rebuild. The increasing trend in biomass and recent substantial reductions in fishing mortality can be reliably determined with the current assessment methods, but technical problems with the assessment preclude the ability to forecast future rebuilding (Stone and Legault 2003). The Transboundary Resources Assessment Committee (TRAC 2003) recommended that a tagging study be conducted on Georges Bank and in adjacent areas to improve the understanding of yellowtail flounder distribution (especially with respect to Closed Area II), confirm age determinations, and provide an independent estimate of mortality.

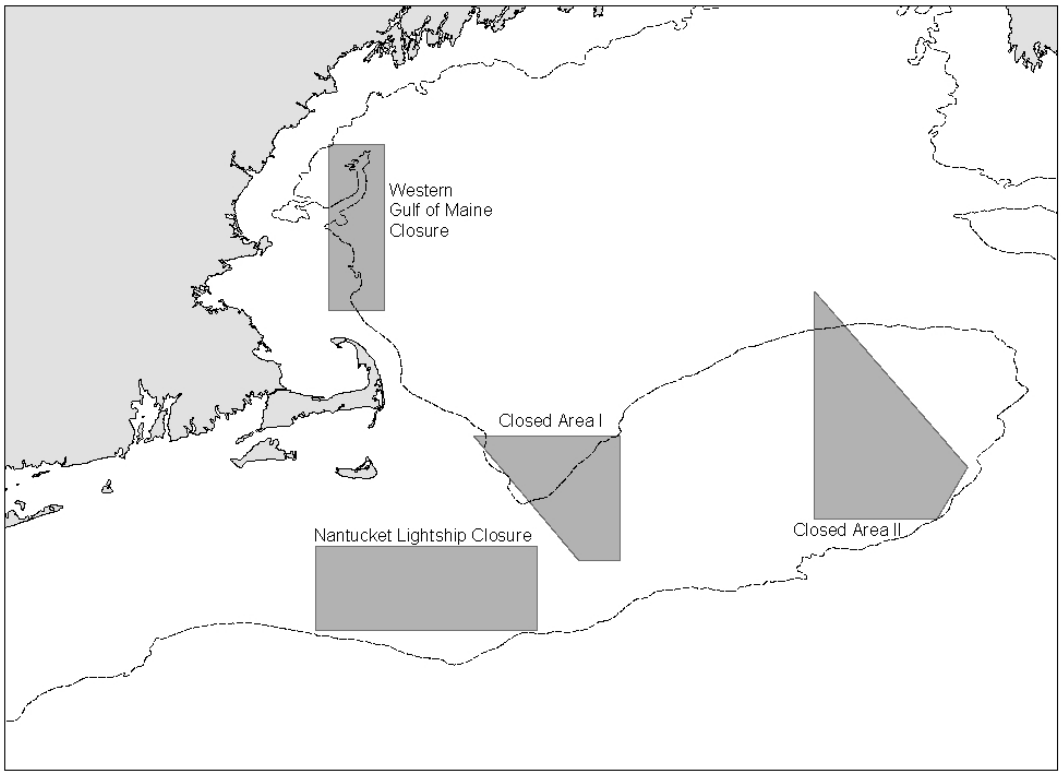


**Figure 2. Year-round area closures for New England groundfish.**

The southern New England-Mid Atlantic stock is rebuilding at a much slower rate than the Georges Bank stock, apparently because fishing mortality has not been effectively reduced, despite management restrictions like the year-round closure of the Nantucket Lightship Area since December 1994. However, recent assessments of stock size have been highly uncertain (e.g., the 1999 assessment was rejected as a basis for stock projections because of inadequate sampling, Cadrin 2001). Although the stock definition of Southern New England-Mid Atlantic yellowtail was recently revised (Cadrin 2003a), information on movement of yellowtail between southern New England and Mid Atlantic areas, as well as mixing with the adjacent Cape Cod and Georges Bank resources is limited to historical studies.

The status of the Cape Cod-Gulf of Maine yellowtail stock is particularly problematic for northeast groundfish management. The stock assessment has a great deal of uncertainty but suggests that recent management efforts have not effectively decreased fishing mortality (Cadrin and King 2003). Therefore, the status of the Cape Cod-Gulf of Maine yellowtail stock is a focus of groundfish management in the Gulf of Maine. The stock assessment is uniquely hampered by the relative absence of fish older than age-5 throughout the assessment and survey time series. Conventional analysis of catch at age produces extremely high mortality estimates. However, surveys indicate a relatively stable stock, suggesting that (1) mortality rates have been overestimated or (2) the stock is not a closed population. Movement of yellowtail to and from the Cape Cod grounds is not well known. Population dynamics of Cape Cod yellowtail may be greatly influenced by mixing with adjacent stocks, because the Cape Cod grounds are relatively small in comparison with Georges Bank and the Southern New England shelf (Hart and Cadrin 2003b). Although data from historical tag recaptures is available, and suggests some mixing with the southern New England and Georges Bank stocks, the studies were not explicitly designed to estimate mortality or mixing rates. These data are up to 50 years old and may not represent the current environmental or stock conditions. The likelihood of older yellowtail moving from the Cape Cod grounds to the northern Gulf of Maine is also not well known.

This proposal is designed to address some of the major sources of uncertainty in yellowtail flounder assessments. A properly designed tagging study can provide valuable information on movement, mortality and growth, thereby complementing the current state of yellowtail assessment science and potentially improving the reliability of scientific advice and effectiveness of fishery management. Furthermore, such cooperative research is expected to build an open working relationship between fishermen, NMFS, state and academic researchers. This proposal was developed with the interaction of fishery scientists and yellowtail fishermen. Industry leaders offered their knowledge of seasonal yellowtail distributions, fishing practices, and practical field experience, and scientists provided input on population modeling, statistical design, and technical protocols. The result is an integrated sampling and analytical plan that is both efficient in the field and technically rigorous for reliable population estimates.

**Review of Previous Work**

As a principal New England groundfish, yellowtail flounder is among the best-studied fishery resources in the world, with decades of studies and publications on its biology and fisheries. However, as with all effective research, each answer produces a host of new questions, and our information on yellowtail populations is far from complete. In fact, recent results from data-storage tags on the Grand Banks suggests that an accurate understanding of basic behavior or yellowtail may be lacking (Morgan and Walsh 2003). Previous work on yellowtail flounder is organized according to our main objectives (movement, mortality and growth) because an integrated analysis of movement and mortality, as proposed here, has not yet been attempted.

Movement

After decades of relying on historical tagging information, the study of yellowtail movements has recently been revived. This proposal is designed to improve a coast-wide comprehensive study of yellowtail movement, mortality and growth that has commenced. The study was designed with the cooperation of northeast fishermen, the Northeast Fisheries Science Center (NEFSC), Massachusetts Division of Marine Fisheries/School for Marine Science and Technology (MADMF/SMAST) and Canada Department of Fisheries and Oceans (DFO) to build on information from previous studies.

Royce et al. (1959) tagged and released 2,597 yellowtail flounder on U.S. fishing grounds from 1942 to 1949 and recovered 377 tags over nearly six years. A seasonal migration was observed from fish tagged in the Mid Atlantic in which most were recovered in southern New England waters during the winter (70% of recaptures) and the rest were recaptured near the release sites. Nearly all of recaptures that were released off southern New England (98%) were recaptured near the release site with one recaptured in the Mid Atlantic and another recaptured on Georges Bank. Nearly all of recaptures that were released on Georges Bank (92%) were recaptured in the same area, but three were recovered in southern New England during winter. All of the recaptures that were tagged on the Cape Cod grounds were recaptured in the same area. Royce et al. (1959) concluded that groups of yellowtail are relatively localized (e.g., most tagged fish were recovered within 80 km of the release site), short seasonal migrations occur, and little mixing occurs among fishing grounds.

Lux (1963) tagged and released 1,800 yellowtail flounder on the three major U.S. fishing grounds from 1955 to 1957 and recovered 431 tags over four years. With subsequent recoveries through 1962 and an additional 3,160 fish tagged in 1959, a total of 4,960 releases and 1,020 recoveries were reported by Lux and Porter (1963). A seasonal migration was observed from fish tagged in southern New England in which most were recovered near the release sites (94% of recaptures), but fish appeared to move to the east in summer (with 2% recovered from Georges Bank and 1% from the Cape Cod grounds) and west in the winter and spring (with 3% of recaptures from the Mid Atlantic). Nearly all of recaptures that were released on Georges Bank (96%) were recaptured in the same area, but five were recovered in southern New England during winter. Nearly all of recaptures that were released off Cape Cod (99%) were recaptured near the release site, with one recovered on Georges Bank in spring, and three recaptured in southern New

England in winter and spring. Lux (1963) concluded that groups of yellowtail move seasonally within fishing grounds with a small amount of seasonal mixing among groups. In 1963, Lux (unpublished) tagged 411 yellowtail flounder off Cape Ann and recorded location of 45 recaptures through 1965. All recaptures were near the release site, except one that moved northward 50 km to the Isles of Shoals.

Tagging studies from Canadian waters confirm that yellowtail flounder are relatively sedentary: the longest observed movement from an unpublished tagging study on the northeast Scotian Shelf was less than 50 km (Neilson et al. 1986), and 475 yellowtail tagged from three studies on the Grand Bank traveled an average of 59 km (Walsh 1987, Morgan and Walsh 1999, Walsh et al. 2001). In 1999, 2156 yellowtail were tagged and released on eastern Georges Bank (Stone and Nelson 2003). To date, 121 yellowtail were recaptured, but none moved off the Bank, and all but one were recaptured on the eastern portion of the Bank. In 2002, 452 yellowtail were tagged and released by DFO in closed area II, and six were recaptured on eastern Georges Bank. These releases and continued fishery recaptures will complement the current and proposed tagging by US fishermen and scientists.

In 2002 and 2003, approximately 200 yellowtail were tagged in the western Gulf of Maine by the University of New Hampshire. The few recaptures reported to date indicate some movement among 30 minute squares.

A summary of all documented yellowtail movements off the northeast U.S. (Table 1; Cadrin 2003b) indicates that only 30% of fish recaptured from release sites in the Mid Atlantic remained in the area (70% moved to southern New England); 95% of fish recaptured from release sites in southern New England remained in the area (2% moved to the mid Atlantic, 2% moved to Georges Bank, and 1% moved to the Cape Cod grounds); 97% of fish recaptured from release sites on Georges Bank remained in the area (3% moved to southern New England); 98% of fish recaptured from release sites on the Cape Cod grounds remained in the area (1% moved to the northern Gulf of Maine, <1% moved to Georges Bank, and 1% moved to southern New England).

**Table 1. Observed movements of yellowtail flounder among stock areas.**

| Release | recapture site | | | | | | proportional recaptures | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | GOM | CC | GB | SNE | MA | sum | GOM | CC | GB | SNE | MA |
| CC | 2 | 345 | 1 | 4 | 0 | 352 | 0.006 | 0.980 | 0.003 | 0.011 | 0.000 |
| GB | 0 | 0 | 263 | 8 | 0 | 271 | 0.000 | 0.000 | 0.970 | 0.030 | 0.000 |
| SNE | 0 | 6 | 15 | 578 | 14 | 613 | 0.000 | 0.010 | 0.024 | 0.943 | 0.023 |
| MA | 0 | 0 | 0 | 64 | 28 | 92 | 0.000 | 0.000 | 0.000 | 0.696 | 0.304 |
| Sum | 2 | 351 | 279 | 654 | 42 | 1328 | | | | | |

Although results from previous tagging work describe yellowtail movements, they were not designed to quantify annual movements. For example, some release sites were close to stock boundaries, increasing the likelihood of movement across the boundary. This proposal, in association with current field work, is more rigorously designed to estimate

population movement rates. In 2002, the National Marine Fisheries Service funded cooperative research to study southern New England-Mid Atlantic yellowtail flounder, including $193,120 for tagging, administered by MADMF/SMAST (IBS 2002). Tagging in SNE-MA will begin in summer 2003. The principal investigators of the SNE-MA tagging project, NEFSC and industry representatives agreed that the SNE-MA tagging study would be more valuable for fisheries management if it was a component of a larger coast-wide study, with a single experimental design, standard protocols, and a single clearing house for tag returns. Therefore a more comprehensive study was designed to expand on the SNE-MA tagging, with release locations in the Gulf of Maine, Cape Cod grounds and on Georges Bank.

In 2003, the NEFSC used operational "Stock Assessment Improvement Program" funds to begin the expanded tagging study by contracting five commercial fishing vessels, tagging yellowtail from the Gulf of Maine to Georges Bank. However, the current funding undersamples the Cape Cod and Georges Bank areas relative to the distribution of the resource and the intensity of tagging in southern New England-Mid Atlantic, compromising the study's ability to quantify movement among stocks.

A recent advancement to tagging fish is the application of computerized data-storage tags that record depth and temperature at regular time intervals. Conventional tags only indicate location of release, location of recapture and time at large, whereas data-storage tags can be used to infer changes in geographic position during time at large. For example, plaice tagged in the North Sea were recovered near the release site, but the temperature and depth record suggests that fish moved from the North Sea to the English Channel, then returned to the release location, giving a completely different perspective than that illustrated by a conventional tag (Metcalfe and Arnold 1997). Data-storage tags were recently applied to yellowtail flounder on the Grand Bank (Walsh et al. 2001). Preliminary results indicate daily vertical migrations of all fish off the bottom at night, throughout the year (Morgan and Walsh 2003). Such information is new and may revolutionize our understanding of yellowtail behavior, ecology and fishery science.

Mortality

Mortality of New England yellowtail flounder stocks has been evaluated for assessed for nearly 50 years using various methods. Royce et al. (1959) estimated of mortality from tagging results from the 1940s, reporting greater mortality on Georges Bank than off Southern New England, and a relatively low mortality off Cape Cod. However, the release sites were not designed to represent the population, and resulting mortality estimates may not be representative. Subsequent tagging data have not been used to estimate mortality.

Stock assessments carried out during the past decade have relied on age-structured virtual population analysis (VPA) calibrated with survey indices of abundance (e.g., Cadrin 2003, Cadrin and King 2003, Stone and Legault 2003). In addition to VPA, non-equilibrium surplus production models have been used to provide alternative perspectives on stock status for Georges Bank and southern New England yellowtail. Results indicate that fishing mortality was extremely high in all three stock areas until the 1990s, when

fishing mortality decreased. However, retrospective comparisons suggest that the VPA assessments tend to underestimate fishing mortality (e.g., when assessments are updated, the estimate of fishing mortality is revised upward, Figure 4). Such retrospective patterns are a major source of uncertainty in the assessment and prohibit accurate forecasts. Based on these concerns, the Groundfish Assessment Review Meeting (NEFSC 2002) and Transboundary Resources Assessment Committee (TRAC 2003) recommended yellowtail tagging studies to provide independent estimates of mortality.

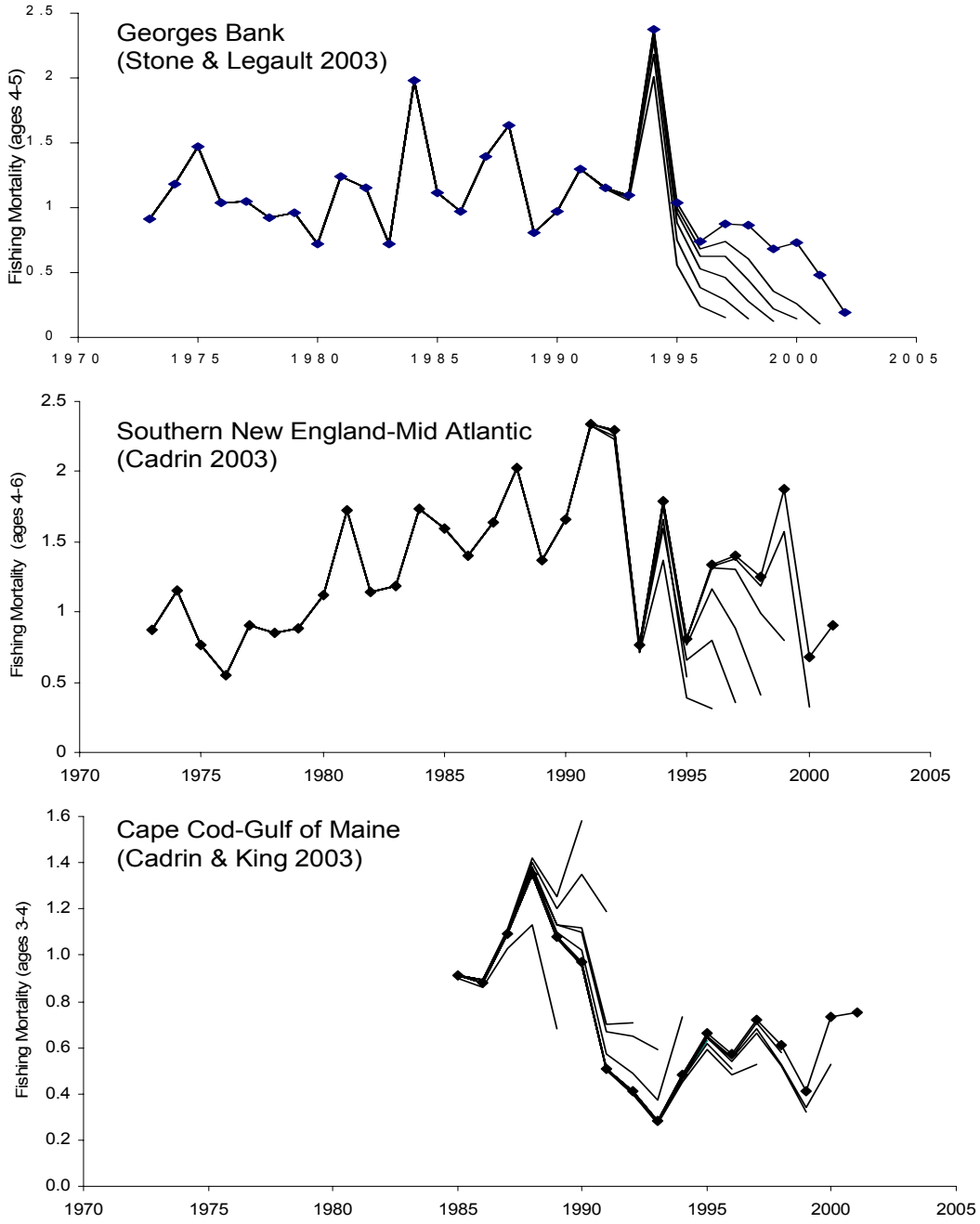


**Figure 4. Current estimates of fishing mortality (indicated by diamonds) and retrospective estimates of fishing mortality (thin lines) illustrating the pattern of underestimating fishing mortality.**

Growth

Age of New England yellowtail flounder is determined by the number of annual growth rings on scales (Figure 4). The method was developed by Royce et al. (1959) and refined by Lux and Nichy (1969) and refined by Pentilla (1988). Although the method is effective for determining the age of relatively young fish (up to age-8), growth rings become more closely spaced at older ages, and age determination is more difficult (Scott 1954, Royce et al. 1959, Lux and Nichy 1969).

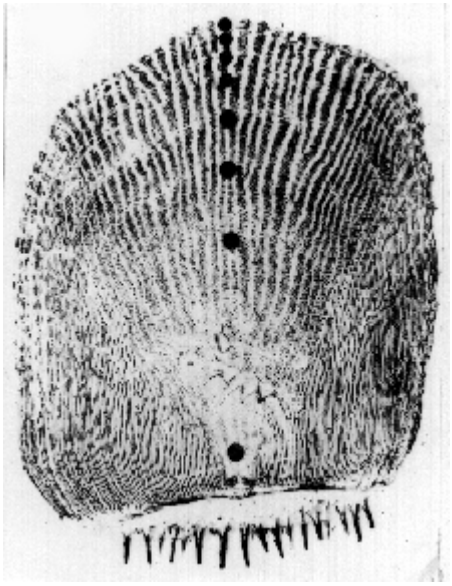

**Figure 4. Scale impression from an age 8 yellowtail flounder from Georges Bank (from Penttila 1988).**

A recent tagging study on the Grand Banks revealed a substantial bias in the determination of yellowtail flounder using otoliths, in which the age of fish was underestimated (Morgan and Walsh 1999). Based on the concern of ageing bias, an international workshop was convened to assess the accuracy of yellowtail age determinations using both scales and otoliths (Walsh and Burnett 2002). The workshop concluded that scale aging was accurate for New England yellowtail up to approximately age-7, but recommended further work on validating the method. Similarly the Transboundary Resources Assessment Committee (TRAC 2003) recommended tagging work to confirm age determinations from scales.

Cooperative Research

A national review of cooperative data collection concluded that successful cooperative research requires the inclusion of fishermen in the study design process (Bernstein and Iudicello 2000). Industry leaders have been intimately involved in the proposed study design, and will continue to provide input in each step of the tag reporting, data analysis and interpretation processes. Estimates of mortality, movement and growth will rely on a high reporting rate of recaptured tags. Therefore, industry support, contribution and investment are essential in making the tagging project a success. Direct and regular contact with industry through vessel contracts and future project planning will also

enhance collaboration. The New England fishing industry and NEFSC have made significant strides in improving their working relationships over the last several years. This tagging study will enhance those efforts further over a longer term.

**Project Objectives and Scientific Hypothesis**

There are several objectives of the Yellowtail Flounder Tagging Study:

- estimate movement rates among yellowtail fishing grounds
- provide independent estimates of mortality for each stock area
- confirm age determinations
- foster cooperative relationships between scientists and fishermen.

The general approach is based on an experimental design that represents the entire population and an analytical design that models simultaneous movement and mortality. Thereby, the experimental design corresponds to the analytical design, and population estimates support all three technical objectives (movement, mortality and growth) with one study.

All phases of the proposed research, from the field protocol to public outreach, have been developed cooperatively between New England groundfish fishermen, the Northeast Fisheries Science Center and other research agencies. Co-principal investigators represent fishermen from all three major fishing grounds (Georges Bank, Southern New England-Mid Atlantic and Cape Cod-Gulf of Maine). Based on the concerns of fishermen and researchers about uncertainty in stock assessments and the need for better understanding of yellowtail movements, a cooperative study has been designed to integrate several ongoing yellowtail tagging efforts.

**Project Plan and Experimental Design**

This proposal to the Northeast Consortium is to contract commercial fishing vessels to tag and release legal-sized yellowtail from the Gulf of Maine to Georges Bank, proportional to geographic patterns of abundance. The basic geographic design is based on statistical fishing areas, with releases near the center of yellowtail habitat in each area (Figure 5). Releasing near the center of the statistical area will best represent the entire area. Such a design will allow estimation of movement among areas and mortality by stock area. Releasing tagged fish in proportion to population distribution and demographics will improve population estimates of movement and mortality. The proposed project is designed to improve the experimental design of concurrent tagging studies for more cost-effective research.

Beginning in summer 2003, approximately 14 days are being chartered to tag yellowtail from the Mid Atlantic Bight to southern New England under the NMFS Cooperative Research Partners Initiative (CRPI), administered by MADMF/SMAST. Despite the crucial need for estimates of movement and mortality for the Cape Cod-Gulf of Maine and Georges Bank yellowtail resources, the CRPI study does not extend beyond the southern New England-Mid Atlantic region. Therefore, the NEFSC allocated operational funds to begin tagging yellowtail in the Cape Cod and Georges Bank areas, beginning in June 2003. However, funding is inadequate to charter the number of days

required to tag yellowtail in proportion to the resource distribution. For example, analysis of NEFSC survey data from 1998-2002 indicates that 39% of the U.S. yellowtail resource is in or near closed area II (statistical area 562), but only 6 days (13% of total tagging effort) is allocated to area 562 in 2003.

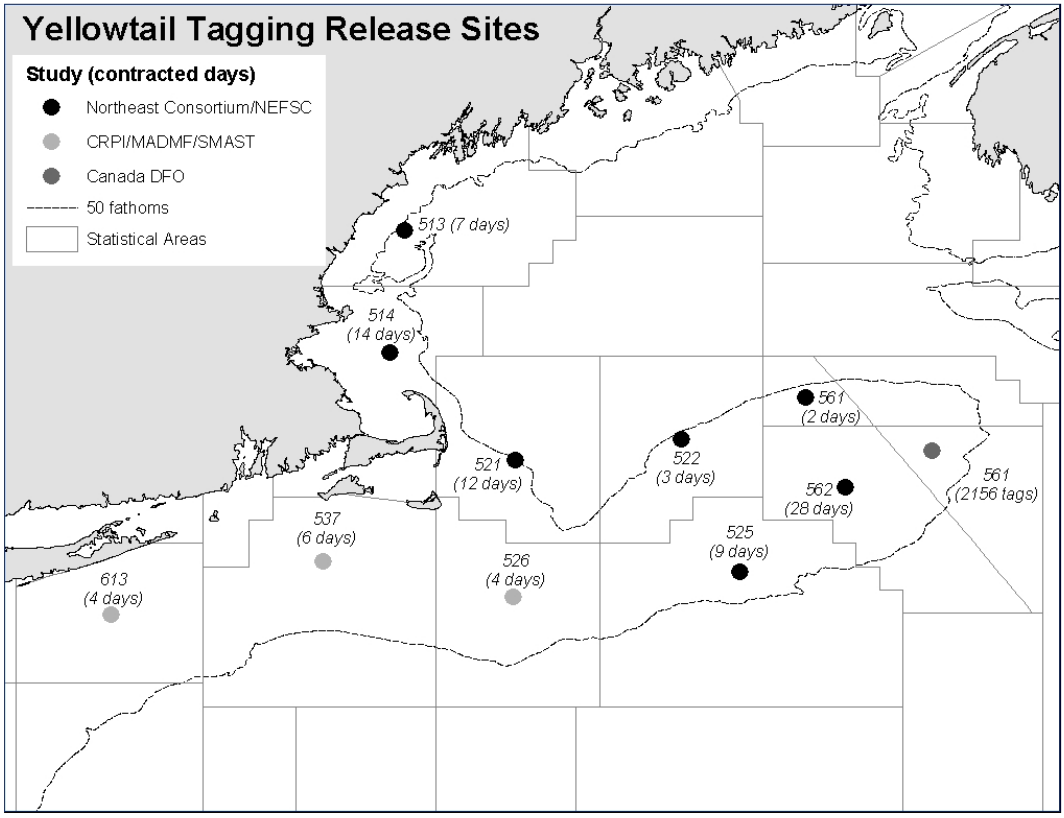


**Figure 5. Proposed experimental design, with allocation of contracted days by statistical area (number of tagging days represents 2003 efforts plus proposed 2004 days).**

Given the relatively high abundance of Georges Bank and Cape Cod yellowtail, the number of tag releases in those areas should be increased to be comparable to the sampling intensity in the southern New England-Mid Atlantic areas. This proposal is based on funding vessel charters to even out the sampling ratio (calculated as the ratio of relative tagging days to relative local abundance of yellowtail resource, Figure 6). Accurate estimates of population movement and mortality should be adjusted according to local abundance. The closer the sampling ratio is to one, the less statistical adjustment will be needed to represent the population.

Principal investigators of concurrent tagging efforts (MADMF/SMAST) have agreed to cooperate with NMFS to integrate the CRPI tagging and Northeast Consortium tagging for a single tagging protocol and common experimental and analytical designs. Canada Department of Fisheries and Oceans began tagging on Georges Bank in 1999 and has also agreed to collaborate on the experimental design and administering Canadian recapture information.

Funding from the Northeast Consortium will provide the necessary cooperation with industry in the form of vessel contracts and local knowledge of yellowtail distribution and seasonal habits, to extend current tagging efforts to the entire U.S. range of yellowtail, and provide estimates of mixing and mortality for all U.S. stocks.

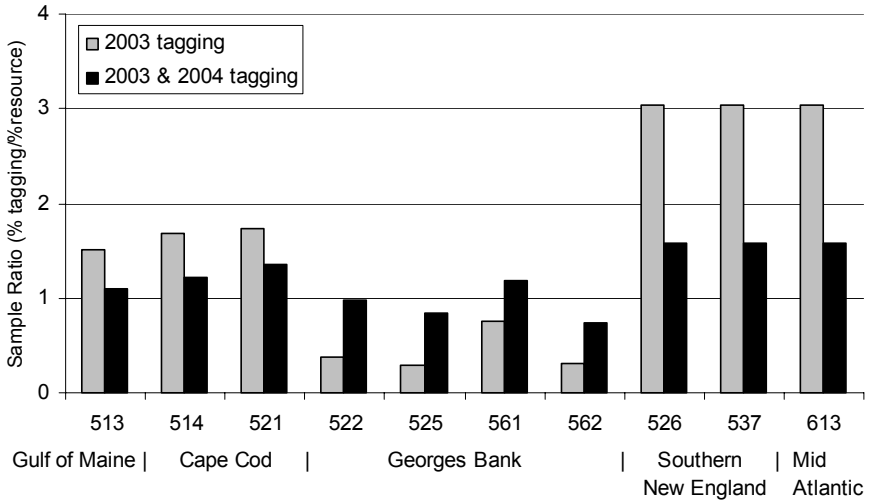


**Figure 6. Allocation of tagging days, expressed as a ratio to local abundance.**

Tagging conducted in June 2003 indicates that approximately 200 yellowtail can be tagged each day, but the number tagged per day varies and is difficult to project. According to the coastwide experimental design, approximately 30,000 yellowtail will be tagged with Peterson disc tags (10,000 purchased by MADMF/SMAST and 20,000 by NEFSC). In addition, 460 yellowtail will be tagged with data-storage tags (100 by MADMF/SMAST, 160 by NEFSC in 2003, and 200 proposed for 2004). A standardized tagging protocol has been developed by fishermen, NEFSC and MADMF/SMAST with several tagging demonstrations and sea trials (see Appendix A).

Reward posters will be produced and distributed to ports from Nova Scotia to the Mid Atlantic. Reporting rates will be assessed with a tiered reward system (e.g., $1,000 lotteries for most tag returns and fewer instant $100 rewards) to allow an estimate of return rate. All tag returns will be reported via a toll-free number (877-826-2612) or online at www.cooperative-tagging.org (see Appendix B). Every reported tag, in addition to a reward (lottery or direct $100), will receive a Certificate of Appreciation, giving details of the tagged fish and its movements. Tag reporters will also be acknowledged on the website, and through annual rewards ($100) to the most frequent tag reporter. Reward posters will be posted, checked and re-posted every month. Project brochures will be distributed at meetings and on the docks, and provided to fishing organizations and tagging participants for distribution. Updates on tagging results and project details will be posted online.

The general approach to cooperative research is to involve fishermen who are both experienced in the yellowtail fisheries and local representatives of the industry. Thus, contractors can not only provide sampling platforms, but also be active in project outreach to maximize tag returns. Personal outreach is essential for success of tagging studies (Bernstein and Iudicello 2000). If funding is awarded by the Consortium for a second year of tagging, new contractors will be sought to increase the representation in the industry and effective outreach (i.e., the five vessels contracted in 2003 will not be awarded contracts in 2004).

The analytical model is based on the assumption that the observed pattern of recaptures is a function of mortality in each area and movement among areas. If the population of tagged yellowtail is representative of the entire population, the estimates of movement and mortality will also be representative. The analytical design will relate the observed number of tag returns to a predicted number of tag returns:

$$\tilde{r}_i^t = n_i^t \beta_i^t \frac{F_i^t \left(1 - e^{-(F+M)}\right)}{\left(F_i^t + M\right)}$$

and

$$n_i^{t+1} = S_i^t \sum_j \alpha_{ij}^t n_j^t$$

where

$n_j^t$ is the number of tags present in area *j* at time *t*

$\beta_i^t$ is the reporting rate in area *i* at time *t*.

$F_i^t$ is the fishing mortality rate in area *i* at time *t*.

$M$ is the natural mortality rate

$\alpha_{i,j}^t$ is the proportion of tags in area *j* that move to area *i* at time *t*

$S_i^t$ is the survival in area *i* at time *t* [$S=e^{-(M+F)}$]

The parameter $\beta_i^t$ will be estimated as the ratio of lottery tag returns to high value ($100) tag returns. The parameters $\alpha_{i,j}^t$ and $F_i^t$ will be estimated by the frequency of seasonal returns by area. In the most aggregated form of the model, the movement matrix among the three stock (Cape Cod-Gulf of Maine, Georges Bank and southern New England-Mid Atlantic) areas is:

$$\begin{bmatrix} \alpha_{CCGOM} & \alpha_{CCGOM,GB} & \alpha_{CCGOM,SNEMA} \\ \alpha_{GB,CCGOM} & \alpha_{GB} & \alpha_{GB,SNEMA} \\ \alpha_{SNEMA,CCGOM} & \alpha_{SNEAMA,GB} & \alpha_{SNEMA} \end{bmatrix} = A$$

where diagonal elements are the proportion of yellowtail that remain in the area of release, off-diagonal elements are movement rates between stock areas, and columns sum to one. The vector of abundance in each are at the end of a time step can then be calculated as the product of an initial abundance vector, a diagonal survival matrix, and the movement matrix ($n_{t+1} = n_t A_t S_t$).

The number of tag returns will dictate how many parameters can be reliably estimated, but the model has flexible spatiotemporal resolution, so that stock areas can be analyzed by statistical areas, and movements can be analyzed by season, if the number of tag returns supports such detail. Therefore, by increasing the number of tag releases and evening the sampling ratios by area, the proposed funding by the Northeast Consortium will improve the resolution and reliability of movement and mortality estimates.

**Available Resources**

The greatest resources available to the project are its personnel. Fishermen and researchers have cooperated to develop the general approach and technical details of the tagging study through several meetings from Rhode Island to Maine. Although many fishermen have provided input and are willing to cooperate for the duration of the project, vessel contracts will go out for bid through Federal requisitions.

Co-Principal Investigators

*Steve Cadrin, Northeast Fisheries Science Center, Woods Hole MA*

Steve has been a fisheries biologist for 18 years, and as a member of the Population Dynamics Branch, is responsible for stock assessments of yellowtail flounder. Steve recently completed a Ph.D. dissertation on "Stock Structure of Yellowtail Flounder" at the University of Rhode Island.

*Azure Westwood, Integrated Statistics, Woods Hole MA*

Azure is a marine biologist under contract with NEFSC to coordinate cooperative research on yellowtail flounder. Azure has experience in community-based fisheries science and management from American Samoa, Alaska and New England.

*Rodney Avila, F/V Trident, New Bedford MA*

Rodney has decades of experience in the Georges Bank yellowtail flounder fishery as an owner and operator of the F/V Trident. Rodney has cooperated in developing tagging protocol and will continue to support outreach activities in New Bedford, where nearly half of the U.S. yellowtail catch is landed.

*Fred Mattera, F/V Travis & Natalie, W. Kingston RI*

Fred is a highliner in the yellowtail fishery and has been instrumental in the development of the industry-based survey for southern New England yellowtail. Fred also provided input for the tagging study design and will coordinate recaptures in the IBS study.

*David Goethel, F/V Ellen Diane, Hampton NH*

David is an experienced New England groundfish fisherman with experience in cod tagging and cooperative research. David has also helped in the experimental design and will continue to help with outreach in the Cape Cod-Gulf of Maine area.

Cooperating Yellowtail Flounder Fishermen

Other New England groundfish fishermen with local experience in yellowtail flounder fisheries from the Gulf of Maine to Georges Bank have expressed interest in cooperating:

Bill Amaru, F/V Joanne-A III, Orleans MA
Frank Avila, F/V Playtime, New Bedford MA
Manuel Catulo, F/V Imigrante, New Bedford MA
Chris Davis, F/V Coming Home, Chatham MA
Firmina Pereira, F/V Cowboy, Westport MA
Carlos Rafael, F/Vs Green Acers and Sasha Lee, New Bedford MA
Luis Ribas, F/V Blue Skies, Provincetown MA
Joe Rogers, F/V Inheritance, Sandwich MA
Antonio Santos, F/V T. Luis, New Bedford MA
Francisco Vicente, Provincetown MA
Proctor Wells, F/V Tenacious, Phippsburg ME

Cooperating Research Agencies

Many people are collaborating on this study and have contributed to its design:
- *NEFSC*: Steve Murawski, Paul Rago, Gary Shepherd, Chris Legault, Jay Burnett, Vaughn Silva and Patricia Yoos
- *MADMF*: David Pierce, Jeremy King and John Boardman
- *SMAST*: Rodney Rountree, Dave Mattens, and Russ Kessler
- *RIDFW*: April Valliere
- *Canada DFO*: Heath Stone

In addition to personnel resources, the proposed study will have the support of NEFSC, providing data (e.g., the commercial weighout database, logbook data, observer program information, and the NEFSC survey database) computational hardware and software, toll-free phone support, website maintenance, and scientific research permits. Industry representatives also have the ability to communicate the objectives of the project to other yellowtail fishermen, thereby maximizing the potential reporting rate of recaptured tags.

**Dissemination of Results, Impacts and Deliverables**

The results from this study will benefit researchers and managers and should help improve the management of yellowtail resources. New information on yellowtail movement, independent estimates of mortality and confirmation of age determinations should be useful for academic, state, and federal scientists and will be important information for fishery managers (i.e., the New England Fishery Management Council). The cooperative approach used in the experimental design will be continued throughout the data collection, analysis and interpretation stages of the study. Therefore, results and conclusions will be a product of all cooperators. Co-principal investigators and others involved in yellowtail tagging will meet annually to review results to date as well as draw lotteries for tag return rewards. Results will be posted on the website (cooperative-tagging.org) and presented to stock assessment workshops (e.g., SAW, TRAC), management meetings (e.g., groundfish committee) and industry groups (e.g., fishermens' forum, Fish Expo) in the form of technical reports and visual presentations.

Deliverables:

- Estimates of total mortality by stock area based on mark-recapture observations.
- Estimates of annual movement rates among areas.
- Confirmation of age determinations through mark and recapture observations.

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**Budget and Budget Justification**

A total of **$200,000** is requested from the Northeast Consortium, 82% of which is allocated to cooperating fishermen (see Appendix C for the Northeast Consortium budget format). Based on the importance of Cape Cod yellowtail for groundfish management in the Gulf of Maine and the recently discovered uncertainties in the stock assessment of Georges Bank yellowtail, the bulk of the proposed budget is allocated to increasing the number of sea days for tagging in the Cape Cod and Georges Bank areas. Additionally, some funding is requested for more data–storage tags, based partly on the novel results becoming available from data-storage tags from the Grand Bank yellowtail study. Costs have been evaluated based on a cost-effective approach to improving the yellowtail tagging study. The budget is itemized below

- Vessel charters: **72%** ($143,000; 10 inshore days at $1,500 per day, 32 offshore days at $4,000 per day – see cost justifications below)
- Reporting rewards: **10%** ($20,000 for lotteries and $100 rewards)
- 200 data storage tags: **18%** ($37,000)
- 20,000 disc tags: provided by NEFSC
- Technicians: observers provided by NEFSC cooperative research allocation in observer contract and Population Dynamics Branch staff
- Outreach (posters and brochures, support of toll-free number and website): provided by NEFSC
- Miscellaneous equipment: provided by NEFSC

<u>Vessel Charter Costs</u>

The going rates for vessel charters for current cooperative research are categorized as inshore day-trips ($1,500 per day for cooperative cod tagging, within the range suggested for Northeast Consortium funding) or multi-day offshore charters ($5,000 per day for the yellowtail industry-based survey and CRPI yellowtail tagging). Based on concerns about the high cost of offshore trips raised by the consortium, two economic analyses are described below that justify a substantial cost differential between inshore and offshore trips. Industry leaders reviewed the economic analyses as well as their own costs and agreed that a cost of $4,000 per offshore day will be acceptable to most cooperators. The revised cost of $4,000 per day is also the initial rate agreed to for the yellowtail tagging and survey work (IBS 2002) before the substantial increase in fuel prices in 2003.

A query of 2002 northeast observer data for otter trawl trips indicated that the 65 observed trips that were at sea for seven days or more were more than 6 times more costly than the 205 observed day trips. Operational costs included damage, supplies, food, water, oil, ice and fuel, but did not include overhead costs (vessel cost, dockage, insurance, etc) which are also greater for larger, offshore vessels:

**Table A1. Reported costs of observed day-trips and multi-day trips in 2002.**

| days | 1-day trips | >7 day trips | cost ratio |
|---|---|---|---|
| trips | 205 | 65 | |
| crew | 1.8 | 4.4 | 2.5 |
| damage | $ .64 | $ 42.96 | 4.5 |
| supplies | $ .20 | $ 13.65 | 1.9 |
| food | $ 4.80 | $ 87.81 | 5.9 |
| water | $ 0.08 | $ 3.93 | 46.6 |
| oil | $ 8.29 | $ 29.11 | 3.5 |
| ice | $ 9.79 | $ 05.92 | 10.8 |
| fuel | $ 70.58 | $ 79.28 | 6.8 |
| cost | $ 20.39 | $ 62.65 | 6.3 |

Similar costs were obtained from an economic survey conducted for an analysis of the economic impacts of Amendment 13 to the Groundfish Plan, (NEFMC 2003; Kitts and Thunberg, NEFSC personal communication). Revenue per day was estimated as $1,521 for an inshore trawler (<50 feet) and $6,254 for an offshore trawler (50-70 feet):

**Table A2. Economic analysis of vessel costs and revenues (Kitts, personal communication)**

| Vessel Category | Mean | Mode | Median | Standard Deviation |
|---|---|---|---|---|
| Trawl < 50 feet: revenue per day | $ 1,521 | $ 609 | $ 1,082 | $ 1,661 |
| Variable costs per day | $ 268 | $ 151 | $ 216 | $ 203 |
| Yearly overhead costs | $ 30,073 | $ 33,680 | $ 30,384 | $ 14,505 |
| Trawl 50 to 70 feet: revenue per day | $ 6,254 | $ 1,063 | $ 3,464 | $ 9,400 |
| Variable costs per day | $ 363 | $ 251 | $ 316 | $ 194 |
| Yearly overhead costs | $ 66,937 | $ 20,835 | $ 42,894 | $ 99,217 |

Based on these analyses, we feel that the proposed vessel costs ($1500 per day inshore and $4000 per day offshore) are justified. The current state of the yellowtail stocks is that much of the resource is offshore, on Georges Bank, where tagging is inherently more expensive. We propose that Consortium funding be used to increase the number of tag releases on Georges Bank and Cape Cod-Gulf of Maine to better represent the current resource.

Data Storage Tag Costs

Data-storage tags are high-technology products that are expensive in comparison to conventional tags. However, the information gained from a single data-storage tag can be extremely valuable (e.g., Metcalfe and Arnold 1999). The manufacturer of the proposed tag, LoTek (based in Newfoundland), is one of three manufacturers of data-storage tags, and offers the most affordable data-storage tag on the market ($185 per tag, including a 10% government discount). Wildlife Computers (based in Washington state) specializes in more advanced data-storage tags that monitor heart rate and light intensity that are $750 or more. Star Oddi (based in Iceland) offers a similar tag to the Lotek tag, but the cost is $368 per tag. Therefore, the LoTek data-storage tag is the most cost-effective product that can meet our needs.