2007 Groundfish Assessment Review Meeting
Working Paper 3E

Yellowtail Flounder Tagging Data

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Abstract
New England fishermen and the Northeast Fisheries Science Center tagged over 45,000 yellowtail flounder in all three New England stock areas. The study was designed to charter commercial fishing vessels to tag yellowtail flounder with conventional disc tags and data-storage tags with the objectives of estimating movement among stocks areas and mortality within stock areas as well as providing growth observations. Preliminary results indicate frequent movements within the Cape Cod and Georges Bank stock areas with a less frequent movement among stock areas. Results are expected to provide information for yellowtail flounder stock assessments and management decisions. This report provides supporting technical information for preliminary estimates of movement and mortality to be reviewed for yellowtail flounder stock assessments (TOR C).

Introduction

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 for yellowtail is among the most productive and valuable in New England, yielding 12 million lb and $14 million to U.S. fishermen in 2003 (NMFS 2004). 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, 2005).

Stock Assessment

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 provide valuable information for fishery management advice, several major sources of uncertainty persist (NEFSC 2005). The traditional assessment of Georges Bank yellowtail tends to overestimate stock size and an alternative assessment model indicates substantially less biomass (Legault et al. 2007). The source of this uncertainty is not well known, but may result from movement among stock areas, lack of information on the effect of closed areas on population dynamics, insufficient surveying of areas closed to fishing, inaccurate age determinations, misrepresentative sampling of distributional patterns, underreported catch, or inaccurate assumptions about natural mortality (NEFSC 2002; TRAC 2004).

The southern New England-Mid Atlantic stock is not rebuilding at an acceptable rate, 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 (Cadrin and Legault 2005). Although the stock definition of Southern New England-Mid Atlantic yellowtail was recently revised (Cadrin 2003), 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 (Royce et al. 1959, Lux 1963a).

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 excessive fishing mortality and decreasing stock size (Cadrin et al. 2005). Therefore, the status of the Cape Cod-Gulf of Maine yellowtail stock is a focus of groundfish management in the Gulf of Maine. However, some surveys indicate a more 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 2004).

Previous Tagging Studies

Movement of yellowtail flounder off New England has been addressed by several historical and more recent tagging studies. Royce et al. (1959) tagged and released yellowtail on U.S. fishing grounds from 1942 to 1949 and 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 (except for frequent movement from the Mid Atlantic Bight to southern New England waters). Lux (1963a) also tagged yellowtail off U.S. fishing grounds and concluded that groups of yellowtail move seasonally within fishing grounds, with a small amount of seasonal mixing among groups.

In 1963, Lux (1963b) tagged yellowtail flounder off Cape Ann. All recaptures were near the release site, except for one fish that moved northward 50 km to the Isles of Shoals. Tagging studies from Canadian waters indicate 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 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).

From 1999 to 2002, yellowtail were tagged and released on eastern Georges Bank (Stone and Nelson, 2003); none of the recaptured fish moved off the Bank, and all but one were recaptured on the eastern portion of the Bank. A summary of all previously published yellowtail movements off the northeast U.S. (Table 1) indicates that 95% of fish tagged in the northern Gulf of Maine moved to the Cape Cod fishing grounds, and 70% of fish released in the Mid Atlantic moved to southern New England. Conversely, nearly all other recaptures were in the area where they were tagged (98% of fish from the Cape Cod grounds, 97% from Georges Bank, and 94%

of recaptures from southern New England). When both Gulf of Maine-Cape Cod and southern New England-Mid Atlantic areas are combined the regional residence is 97%.

Although data from historical tag recaptures is available (Royce et al. 1959, Lux 1963a), 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.

Objectives

The yellowtail flounder tagging study was designed to address the major sources of uncertainty in yellowtail flounder assessments. The study provides valuable information on movement, mortality and growth, thereby complementing the current stock assessment methods for yellowtail and improving the reliability of scientific advice for effective fishery management. Furthermore, such cooperative research is building an open working relationship between fishermen, NMFS, state and academic researchers. This proposal was developed with the interaction of fishery scientists and yellowtail fishermen. Through a series of port visits and meetings, industry leaders offer 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.

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.

Methods

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.
This project contracts commercial fishermen and their vessels to work with scientists to tag and release yellowtail on all fishing grounds off New England, proportional to geographic patterns of abundance. The geographic design is based on statistical fishing areas, with releases in each area proportional to relative abundance of yellowtail (according to NEFSC groundfish surveys). Such

a design allows for the estimation of movement among areas and mortality by area. The field protocol and analytical design were peer reviewed at "a workshop to review and evaluate the design and utility of fish mark - recapture projects in the northeastern United States" and considered to be a valid approach to address the project objectives (Tallack et al, eds. 2005).

Tag Deployment: Yellowtail are captured using commercial otter trawls with large mesh (6.5") and relatively short tows (30 min). All legal-sized fish (>33cm) in viable condition, and some sublegal sized-fish from low density tows in southern New England-Mid Atlantic are tagged with either Peterson discs or data-storage tags. Releases are during the spawning season (May-August; with the exception of 1% of releases in autumn of 2003). Tag specifications are:

- Peterson Discs; Floy Tag 7/8" round, fluorescent pink, labeled "cooperative-tagging.org, tag#, $1000 lottery (or $100 reward), toll free 877-826-2612, provide tags & location and date." Most fish tagged blank on blind side, scales plucked from approximately 10%, tags on blind side labeled "take some fish scales & return to 166 Water Street Woods Hole MA 02543."
- Data-storage tags; Lotek LTD 1100, 32K memory, 8mm x 16mm x 27mm; time (dynamic storage & intervals), depth (+/- 0.04psi up to 735psi) & temperature (+/- 0.19o C), 3 year battery, labeled "tag#, Mail tag, date, location to 166 Water Street Woods Hole MA 02543". Oval disc tag labeled "cooperative-tagging.org, $100 reward, toll free 877-826-2612."

A more detailed field protocol is provided in Appendix A.

Tag Recapture and Outreach System: Tag recaptures are from a year-round commercial fishery with some seasonal geographic closures. The reward system for reporting recaptures involves $1000 lottery tags, 280 high-value ($100) rewards, and $100 rewards for returning data-storage tags. The outreach system includes reward posters, brochures, website (cooperative-tagging.org), annual letters to yellowtail fishermen, press releases, and a toll free number (877-826-2612). Every fisherman who reports a recapture is contacted via a phone call and 'thank you' letter with a map detailing movements of the tagged fish. Fishermen who return data storage tags, also receive a graph of the temperature and pressure data from that tag. Mailings and posters about the program have also been distributed to fish processors, fishing associations, NMFS port agents, NMFS Observer Program and research institutions from Nova Scotia to New Jersey. Project hats are given to leading tag returns and collaborators.

In response to suggestions at the 2nd Annual Yellowtail Tagging meeting (May 2 2005, Woods Hole), a new double-sided reward poster with information detailing the project was designed. The poster incorporated pictures of the new $100 yellow disk tag and new orange scale blanks. Posters are translated in Portuguese, French and Spanish to foster better communication between scientists and fishermen in New Bedford and Canada. To compliment the new database, phone logs have been carefully revised to collect more information without compromising critical recapture information. Scale envelopes labeled with yellowtail tagging pertinent info have been distributed throughout the ports by key cooperators and through mailings. Discussions at the the 3rd Annual meeting (March 1 2006, New Bedford) focused on understanding recapture patterns and increasing outreach to fisheries that catch yellowtail incidentally.

Since the project began in 2003, 103 $100 rewards have been issued and nine $1000 lottery drawings have been hosted at fishing venues throughout New England. In addition to the standard "thank you" letters and maps, the project initiated an "Outstanding Partner" Award to the vessel with the most tag returns. A framed certificate and "thank you" letter signed by the Director of the NEFSC is mailed to the partner and posters announcing the merit are distributed for display in fishing supply houses and around the waterfront. This year, the award went to the F/V Voyager I out of New Bedford, MA (Captains Fred Marques and Tony Fernandes).

The toll free number for reporting tags (877-826-2612) is maintained and answered by a project coordinator at NEFSC. The website was updated to include more information and a user-friendly appearance. Several new features include a "Porthole Page", new stock assessments, a policy on lottery drawings and recent publications. The website is maintained and updated regularly with press releases, lottery winners, and data tag returns.

Analytical Design

The analytical model is based on the assumption that the observed pattern of recaptures is a function of harvest rate 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 (r) to a predicted number of tag returns:

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

and tags at the beginning of a time step is a function of abundance at the beginning of the time step in all areas, movement to the area (or residence in the area) and survival in the area:

2) $$n_i^{t+1} = \sum_j \alpha_{ij}^t S_j^t n_j^t$$

where

n_j^t	is the number of tags present in area *j* at time *t*
β_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 β_i^t can be calculated as the ratio of lottery tag returns to high value ($100) tag returns, assuming that all recaptures if $100 tags are reported. The parameters $\alpha_{i,j}^t$ (movement) and F_i^t (fishing mortality) can be estimated to fit model predictions to the observed frequency of seasonal returns by area.

The number of tag returns and the duration of the study will dictate how many parameters can be reliably estimated. 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.

Data – Modifications and improvements to the existing yellowtail flounder tagging database were made in the spring of 2005 and continued through 2007. The 2003 and 2004 tagging data underwent rigorous quality control procedures, resulting in the correction of many data entry errors. This process, although time consuming, improved the quality of the existing data and resulted in changes to the structure of the database. Tagging data from 2005 and 2006 were entered into a modified relational database with online audit features. In August 2007, all audited data were loaded to a fully-relational database, and tag recaptures are entered directly to the master database.

Several data fields were added to improve our ability to quickly summarize the release and recapture data and generate GIS maps for outreach. The individual tag release records have been linked to the tow data, resulting in location information for every tag. The quality of the recapture data has been greatly improved through this process. Vessel hull numbers have been added to keep better track of participating vessels. A lookup table has been added that produces the statistical area where fish were recaptured. The addition of fields for data quality coding (i.e.: recapture data and recapture location) has enabled the data to be filtered by quality of data.

The structural changes to the database led to modifications of our field protocol. The field data sheets were re-designed and preparations for field work were changed to further improve data collection at sea. The data sheets now have record numbers for each fish tagged, tag series are assigned to scientists to improve record keeping, and standardized comment codes related to fish condition have been added. Additionally, prior to field work, tags are organized in sequential order for deployment to minimize recording errors. These changes have greatly improved the quality and efficiency of data collection in the 2005 tagging season.

The transition to a relational database greatly improves our ability to analyze these data. We now have the capability to link to other NEFSC databases such as the weighout and logbook data. Additionally, the yellowtail flounder data are being used as a model for the design of a multi-species mark-recapture database which will house data from all NEFSC tagging projects.

Data from tag releases and recaptures are continually being added to the yellowtail tagging database. When the project is complete, a comprehensive database will be provided to the Consortium. Preliminary data can be provided upon request. The Northeast Fisheries Science Center has dedicated resources to maintain the yellowtail tagging database indefinitely as a part of the NEFSC Data Management System.

Interim Results

Tag releases – Tagging began in 2003 from 7 vessels (35 days of tagging), continued in 2004 (12 vessels, 57 days), 2005 (4 vessels, 23 days) and 2006 (7 vessels, 44 days). A total of 45,653 tags were released from 2003 to 2006 (Table 2). Releases consisted of 44,492 lottery tags, 381 high-value reward tags and 780 data-storage tags. Tag releases were approximately proportional to survey estimates of relative biomass by statistical area (Figure 2, Table 3).

Tank and Cage Experiments
Holding experiments were performed to assess tag retention and tagging-induced mortality. In 2004 and 2005, tank experiments were conducted to assess tag-induced mortality. On the last tow of four inshore tagging trips, 30 fish were kept in a flow-through tank on board, and transported to a flow through holding tank in Woods Hole via oxygenated shipping bags maintained at approximately 10°C. Fish were fed regularly and observed daily. One experiment observed 20 tagged fish and 10 untagged controls for 35 days. They were also held for up to a year to observe tag retention. A second experiment acclimated 30 untagged fish for 2 weeks, after which 20 were tagged. Subsamples were removed from the holding tank at durations of 0, 24 and 168 hrs. Tissue samples around the tag site were preserved and analyzed for histological reaction at the University of Maryland Fish Pathology Lab.

Results from the first tank experiment showed different patterns of mortality which suggests tag-induced mortality may be substantial, but better controls are needed. Results from the second holding experiment showed no histological reaction at the tag sites, so the mortality observed in holding experiments may not be related to tagging. The long-term holding study observed no tags lost, with some fish held for over a year.

In 2005, we designed small cages and a deployment system to evaluate tagging-induced mortality of yellowtail flounder, a necessary component of the tagging study. Cages are cylindrical (6' diameter, 2' high), made of 1-inch coated wire mesh, with two 50" cement runners for stability. Cages were initially deployed in 24-26 fathoms. Our experimental design involved collecting yellowtail in Ipswich Bay using tagging protocol (i.e., short tows with little bycatch of other species and immediate placement in flow-through tanks). We tagged 15 fish and placed them in a cage floating at the surface by the boat. We also placed 15 untagged fish in the cage for control observations. Tagged and control fish were selected using the quality control procedures in the tagging protocol to insure that viable fish are included in the study. Cages were lowered to the bottom. Oceanographic equipment (Hydrolab©) was deployed on a cage during deployment to monitor water quality during the experiment.

After three or four days, cages were hauled to the surface to observe survival of tagged and control fish. The ratio of survival of tagged and control fish was used to estimate tag-induced mortality. Survival of all tagged and control fish is an alternative estimate of mortality that includes that trawl-capture system. Tissues were collected from five tagged fish and three control fish from each cage deployment to assess tag-induced stress. Preserved tissues will be analyzed by the University of Maryland Fish Pathology Lab for histological examination. Tissue analysis is funded by the Living Marine Resources Cooperative Research Center, associated with tank studies for yellowtail flounder. Each of the three cages was loaded with fish and deployed four times (totaling 12 deployments with 360 fish) from June 6 to 20, 2005. Cages were retrieved after three or four days. Fish were inspected for viability and condition and subsampled for tissue analysis.

Tag Recaptures – As of August 1 2007, tags from 3,618 recaptured fish were reported (Table 4). Preliminary results indicate frequent movements within the Cape Cod and Georges Bank stock areas with a less frequent movement among stock areas. Recapture data indicate 96% residence in Cape Cod-Gulf of Maine (with 3% movement to Georges Bank and 1% movement to southern

New England-Mid Atlantic), 98% residence on Georges Bank (with 1% movement to Cape Cod-Gulf of Maine and <1% movement to southern New England-Mid Atlantic), and 47% residence in southern New England-Mid Atlantic (with 39% movement to Georges Bank and 13% movement to southern Cape Cod-Gulf of Maine; Table 5). However, most movement from southern New England to Georges Bank was from the Nantucket Shoals area (Figure 3).

Eight percent of all lottery tags have been returned; 13% of $100 reward tags and 10% of data tags were returned. The relative return rate of lottery tags to high-value tags indicates a 59% reporting rate (Table 4), which is exceptional for a commercial fishery. An analysis of recapture rate by sex, size, condition code and damage code (Table 6) indicates that females had a greater recapture rate than males (particularly small males), fish categorized as ‘good’ had the same recapture rates as those that were ‘excellent,’ and all damage codes had similar recapture rates (except ‘net marks’ which may be excluded from mortality analyses and ‘lymphocystis’ which is a natural condition).

Tag Retention and Tag-Induced Mortality

Results from the cage experiments indicated low overall mortality of tagged and control fish. Of the 360 fish in the experiment, only 15 died, and more control fish died than tagged fish. Six fish died in the second deployment, which was associated with poor weather conditions and cage movement. Therefore, it appears that the trawl-capture and caging system impose more mortality than tagging. Analysis indicates no tag-induced mortality, because more control fish died than tagged fish, and approximately 3% mortality from the capture and cage system. Exclusion of data from a cage where sandfleas were observed eating live fish, suggests a 1% mortality from the trawl-capture system.

The cage experiments were considered so successful and efficient that they were also conducted on Georges Bank in summer 2005. Although deploying cages offshore was more difficult, results also suggested low to negligible tag induced mortality. In 2006, cage experiments were conducted with each release event to improve estimates of tag-induced mortality. Preliminary results confirm a minimal tag-induced mortality.

Data-storage tags

Sixty data-storage tags were returned, indicating distinct off-bottom movements (Cadrin and Moser 2006). All tags at large more than one month indicated distinct off-bottom movements. Off-bottom movements were typically in evening hours, between 18:00 and 22:00, lasting an average of four hours, ascending to an average of 15m off-bottom (Cadrin and Westwood 2004). The frequency of off-bottom movements varied geographically, an average of once every ten days off Cape Cod, and once every three days on Georges Bank.

These results illustrate how archival tags enhance the interpretability and power of tagging studies. Until recently, the well-studied yellowtail flounder was thought to be a "sedentary" fish, feeding on epibenthic fauna and limited to relatively shallow, sandy habitats. This strict habitat preference and the discontinuous distributions of such habitats were considered to limit movement among offshore banks and shelves, thereby maintaining geographic stock structure. The movement patterns indicated by disc tags likely involves passive drift in midwater currents, similar to patterns observed for other flatfish species. Therefore, the use of electronic tags reveals an important aspect of yellowtail behavior that was not apparent after decades of intense research.

Ageing Confirmation
Scale samples from released and recaptured fish have not been processed for age determination or marginal increment analysis.

Analytical Results
Although many tagged yellowtail are still at large and recaptures continue to be reported, all release and recapture information through August 1 2007 (i.e., four annual release events and four years of recaptures) were analyzed to assess the possible uses of tagging data for the 2008 yellowtail stock assessments. Accordingly, all results in this WP and associated Working Papers should be considered to be preliminary. Although the study was explicitly designed for the movement-mortality analysis described above, the proportional release design and ancillary studies (high-value tag reporting rate, holding studies) support alternative analyses. A range of analytical approaches are being applied to the yellowtail tagging data (the first three are reported in accompanying GARM Working Papers):

- <u>Movement-Mortality Analyses of Yellowtail Flounder Tagging Data</u> (Cadrin GARM WP3F) - Preliminary applications of the analytical model described above were reviewed at the 2005 and 2006 cooperators' meetings, as well as the pre-GARM tagging meeting in August 2007, and have gone through several revisions. WP3F document results presented at the 2007 meeting.
- <u>Evaluating the Precision and Accuracy of the Yellowtail Flounder Movement-Mortality via Simulation</u> (Alade and Cadrin GARM WP3G) – Performance of the analytical model described above is evaluated by simulating a population that emulates the yellowtail flounder population and tagging data. WP3G presents interim results from ongoing simulation analyses.
- <u>Estimation of Mortality from Yellowtail Flounder Tagging Data</u> (Wood and Cadrin GARM WP3H) – Conventional mark-recapture models (White and Burnham 2007) are applied to yellowtail tagging data as a single population (Mid Atlantic to the Gulf of Maine) to estimate mortality as well as optimal model configuration (e.g., optimal time step and time-varying parameters).
- <u>Application of a Likelihood-based Movement Model to Yellowtail Flounder</u> (Wood and Cadrin, in process) – Hilborn's (1990) model, when modified for a continuous fishery, involves the same process equations described above, but can be evaluated in a likelihood framework. This analysis will be completed as part of the National Research Council Associate Program.
- <u>A Spatially Explicit Stock Assessment Model of Yellowtail Flounder</u> (Goethel, Cadrin, Legault and Rothschild, in process) – A stock assessment model developed to integrate typical assessment data (e.g., catch-at-age and abundance indices) with information on movement among stock areas from tagging data (Porch 2003) will be expanded to three stock areas for application to yellowtail assessment and tagging data. This analysis will be completed as part of the NOAA/UMass CMER Program and the Massachusetts Marine Fisheries Institute.

- Movement of Yellowtail Flounder in Closed Areas (Melgey, Cadrin and Stokesbury, in process) – Yellowtail tagging data will be used in conjunction with survey and observer data to evaluate movement patterns and rates in relation to closed area boundaries. The results may help to assess potential patterns of survey catchability and disagreements between survey and fishery data. This analysis will be completed as part of the NOAA/UMass CMER Program and the Massachusetts Marine Fisheries Institute.

Discussion

This study was designed to benefit researchers and managers, helping to 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 is being continued throughout the data collection, analysis and interpretation stages of the study. Therefore, results and conclusions will be a product of all cooperators.

Participants and Acknowledgments

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. All cooperators were invited to three meetings to reflect on field work, review results and plan future work. Six fishermen and 33 scientists attended the first meeting in Woods Hole on January 14, 2004. Seven fishermen and 29 scientists attended the second meeting in Woods Hole on May 2, 2005. Twenty-one fishermen and 13 scientists attended the third meeting in New Bedford on March 1, 2006. Detailed summaries of the meetings are available online (www.cooperative-tagging.org).

Many fishermen have contributed to this study. David Goethel (F/V Ellen Diane) and Fred Mattera (F/V Travis & Natalie) have been involved in all aspects of planning and interim decision making. Other fishermen who have been involved in tagging and attending planning meetings: Carlos Ageuas (F/V Victory), Bill and Jason Amaru (F/V JoAnne-A III), Rodney Avila Sr. and Rodney Avila Jr. (F/V Trident), Bruce Bannick (F/V Sarah Beth), Ed Barrett (F/V Phoenix and F/V Sirius), Antonio Barroqueiro (F/V Lady of Grace), Tom Bell (F/V Karoline Marie), Tony Borges (F/V Sao Paulo), Ron Borjeson (F/V Angenette), Carl Bouchard (F/V Stormy Weather), Ray and Rich Canastra (Whaling City Auction), Luis Fidalgo (F/V Vila De Ilhavo), Steve Follette (F/V Heather Lynn), Jim Ford (F/V Lisa Ann II), Paul Harvey (F/V Ing Toffer II), Manny Marquintos (F/V Victory), Luis Martins (F/V Victory), Shawn McLellan (F/V Elizabeth), Maggie and John Raymond (F/V Olympia), Luis Ribas (F/V Blue Skies), Dennis Robillard, Jr. (F/V Julie Ann) and Jaime Santos (F/V Lady of Grace), Tracy Stubbs (F/V Ing Toffer II) and Proctor Wells (F/V Tenacious), and dozens more have returned tags.

Many scientists are collaborating on this study and have contributed to its design:

- *NMFS*: Steve Murawski, John Boreman, Frank Almeida, Fred Serchuk, John Hoey, Paul Rago, Chris Legault, Cathy Sumi, Stacy Kubis, Tony Wood, Talia Bigelow, Gary Shepherd, Bill Overholtz, Nathan Keith, Jonathan Duquette, Rob Johnston, Kevin McIntosh, Bill Duffy, Dave Radosh, Jay Burnett, Sarah Pregracke, Vaughn Silva, Patricia Yoos, Heather Sagar, Earl

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- *Canada DFO*: Heath Stone
- *University of Maryland*: Eric May, Andrea Johnson and Erica Anuszewski
- *Northeast Consortium, University of New Hampshire:* Chris Glass, Rachel Gallant
- *Manomet Center*: Greg Morris and Kris Joppe-Mercure
- *REMSA Observers:* Janine L'Heureux and Meryl Segal
In addition to personnel resources (including all scientific field staff), the proposed study has the support of the Northeast Fisheries Science Center, 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 have the ability to communicate the objectives of the project to other yellowtail fishermen, thereby maximizing the potential reporting rate of recaptured tags.

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Table 1. Previously observed movements of yellowtail flounder among stock areas (GOM: northern Gulf of Maine; CC: Cape Cod; GB: Georges Bank; SNE: southern New England; MA: mid Atlantic).

Royce *et al.* (1959): 2597 tagged at 14 locations during 1942-1948

release	recapture site						proportional recaptures				
site	GOM	CC	GB	SNE	MA	sum	GOM	CC	GB	SNE	MA
CC	1	**38**	0	1	0	40	0.03	**0.95**	0.00	0.03	0.00
GB	0	0	**34**	3	0	37	0.00	0.00	**0.92**	0.08	0.00
SNE	0	0	1	**82**	1	84	0.00	0.00	0.01	**0.98**	0.01
MA	0	0	0	64	**28**	92	0.00	0.00	0.00	0.70	**0.30**
sum	1	38	35	150	29	253					

Lux (1963), Lux & Porter 1963: 4960 tagged at 15 locations during 1957-1959

release	recapture site						proportional recaptures				
site	GOM	CC	GB	SNE	MA	sum	GOM	CC	GB	SNE	MA
CC	0	**262**	1	3	0	266	0.00	**0.98**	0.00	0.01	0.00
GB	0	0	**114**	5	0	119	0.00	0.00	**0.96**	0.04	0.00
SNE	0	6	14	**496**	13	529	0.00	0.01	0.03	**0.94**	0.02
sum	0	268	129	504	13	914					

Lux (unpublished): 411 tagged at 3 locations in 1963

release	recapture site						proportional recaptures				
site	GOM	CC	GB	SNE	MA	sum	GOM	CC	GB	SNE	MA
CC	1	**45**	0	0	0	46	0.02	**0.98**	0.00	0.00	0.00

Stone (unpublished): 2156 tagged at 1 location in 1999

release	recapture site						proportional recaptures				
site	GOM	CC	GB	SNE	MA	sum	GOM	CC	GB	SNE	MA
GB	0	0	**110**	0	0	110	0.00	0.00	**1.00**	0.00	0.00

Summary

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	**258**	8	0	266	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	274	654	42	1323					

Table 2. Releases of tagged yellowtail flounder by stock area, tag type and year.

Year	Stock Area	Lottery Tags	$100 Tags	Data Tags	Total
2003	CCGOM	4,229	50	114	4,393
	GB	4,164	29	56	4,249
	SNEMA	778	9	33	820
	All	9,171	88	203	9,462
2004	CCGOM	2,765	14	33	2,812
	GB	14,587	64	133	14,784
	SNEMA	1,649	14	76	1,739
	All	19,001	92	242	19,335
2005	CCGOM	1,111	10	-	1,121
	GB	4,595	78	134	4,807
	SNEMA	627	12	-	639
	All	6,333	100	134	6,567
2006	CCGOM	3,152	37	-	3,189
	GB	5,186	57	201	5,444
	SNEMA	1,649	7	-	1,656
	All	9,987	101	201	10,289
2003-2006	CCGOM	11,257	111	147	11,515
	GB	28,532	228	524	29,284
	SNEMA	4,703	42	109	4,854
	All	44,492	381	780	45,653

Table 3. Distribution of tag releases by statistical area in comparison to survey biomass.

	Tag Releases					2003-2006
area	2003	2004	2005	2006	Grand Total	survey
513	3	1392	247	943	2585	13%
514	2025	1192	480	1616	5313	19%
521	2129	43	378	393	2943	4%
522	710	784	84	686	2264	5%
525	118	3978	817	459	5372	4%
526	117	524	32	1202	1875	3%
537	199	269	284	283	1035	4%
539	170	30	0	101	301	1%
561	423	476	57	534	1490	5%
562	2906	9096	3387	3072	18461	40%
613	292	331	231	205	1059	3%
Total	9092	18292	6242	9494	43120	100%

Table 4. Total releases and recaptures by tag type.

tag type	releases	recaptures	%
lottery tags	44492	3489	8%
$100 tags	381	51	13%
DSTs	780	78	10%
sum	45653	3618	8%
%lottery / %$100			0.59

Table 5. Frequency of recaptured tags with known area of recapture by stock area.

Release	Recapture Stock				Recapture Stock			
Stock	CCGOM	GB	SNEMA	sum	CCGOM	GB	SNEMA	
CCGOM	986	35	8	1029	96%	3%	1%	100%
GB	27	2248	9	2284	1%	98%	0%	100%
SNEMA	12	42	35	89	13%	47%	39%	100%
total				3402				

Table 6. Recapture rate (recaptures/releases) by category.

Sex	recap/rel
female	8%
male	6%

Sex, Condition	
female, excellent	9%
female, good	8%
male, excellent	6%
male, good	6%

Female size range	
33-35cm	8%
36-38cm	9%
39-41cm	8%
42-44cm	8%
45-47cm	8%
48-55cm	9%

Male size range	
33-35cm	7%
36-38cm	5%
39-41cm	5%
42-44cm	10%
45-47cm	8%
48-55cm	9%

Condition	Recap/Rel
excellent	8%
good	8%

Damage Code	Recap/Rel
anal tear	9%
bruising	8%
ambicoloration	8%
ripe	8%
old wound	8%
fin damage	7%
sea lice	7%
abrasions	7%
fin tear	6%
anal extrusion	6%
scale loss	6%
net marks	5%
lymphocystis	3%

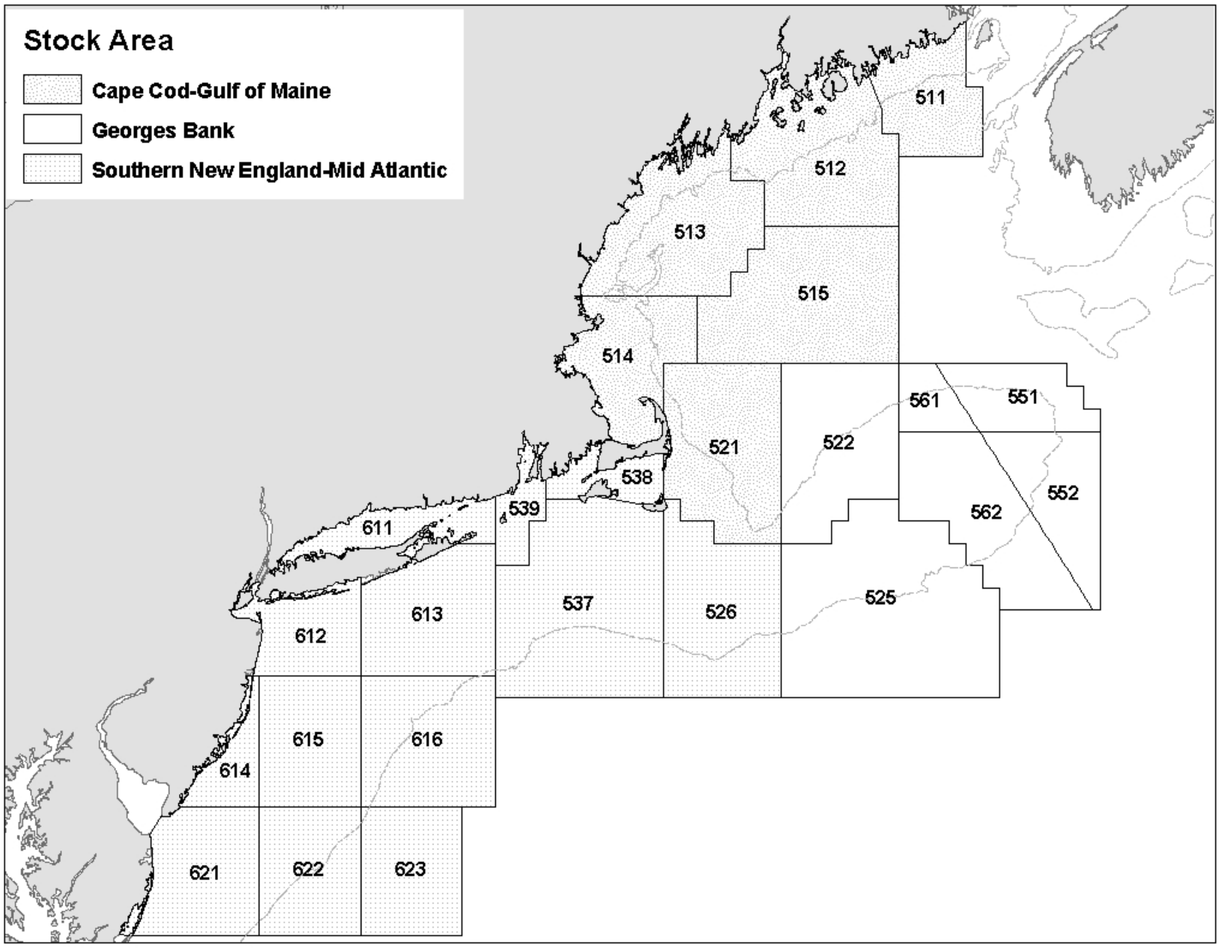

Figure 1. Yellowtail flounder management areas off the northeastern U.S.

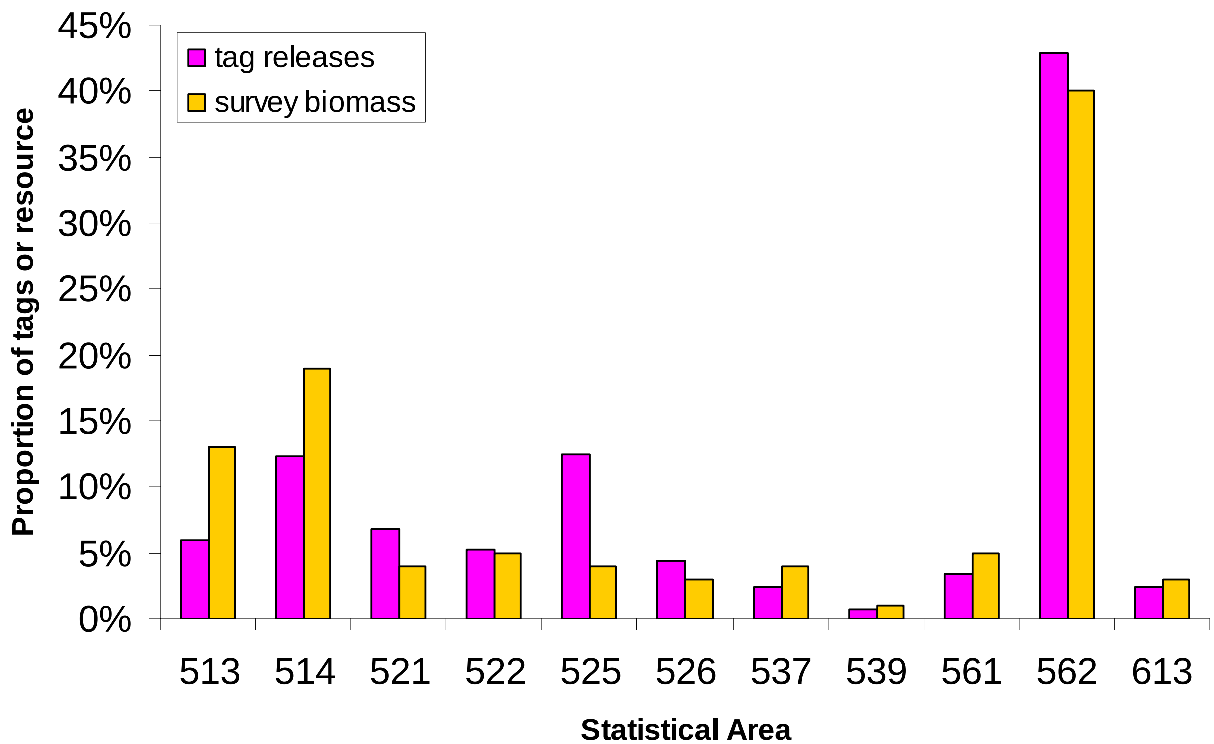

Figure 2. Distribution of tag releases by statistical area in comparison to survey biomass.

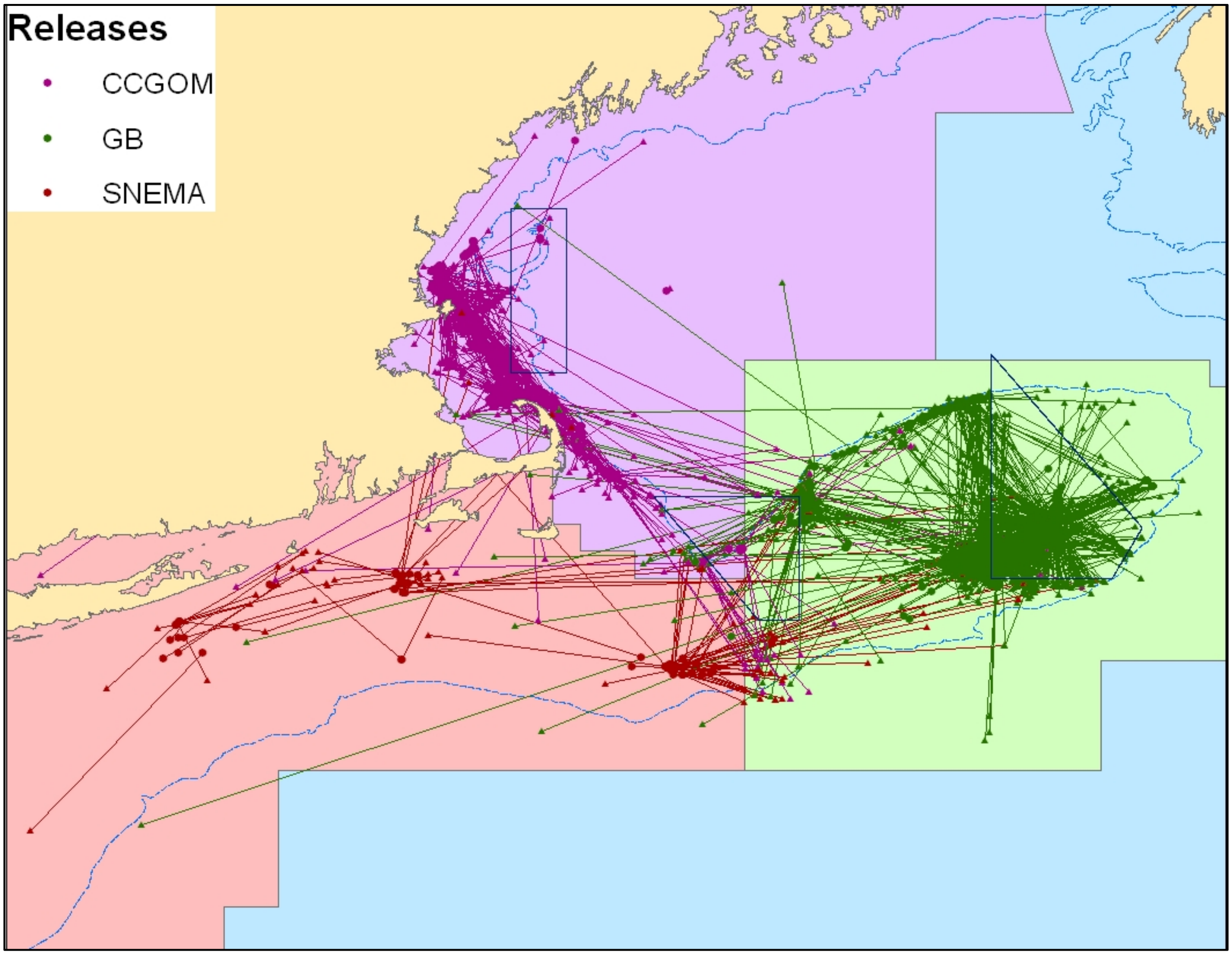

Figure 3. Release (circles) and recapture (triangle) locations from reported tag recaptures, colors represent management area of release.

Appendix A. Tagging and Data Collection Protocol

Tagging Check List

PAPERWORK/OTHER
- Captain's Haul Logs
- Scientific Research Permits
- Tagging Data Sheets (water-resistant)
- Clip board
- Scale envelopes
- Mechanical pencils/lead, paper clips
- Camera
- Field season folder with info

CAGE EQUIPMENT
- 3 cages
- 3 high fliers
- 3 buoys (+any extras deemed necessary for floatation
- Buoy lines, extra line
- Anchor lines + anchors (if necessary)
- Hog rings and hog ring pliers
- Hydrolab
- Video camera

How to fill out Captain's Log

- The Captain and Chief scientists are to arrange specific areas to fish based on the contract agreement prior to departure.
- Insure that the captain has enough haul logs for the trip. Explain how to properly fill out the sheets. Fill in all fields on the data sheet. Important points to remember:

– *Trip ID:* On day trips, each day is entered as a new number (i.e. Day 1 = 01, Day 2 = 02, etc.) For trips of duration greater than 1 day, the same number should be entered for every day aboard the same vessel (i.e. Day 1 = 10, Day 2 = 10, etc.)
– *Haul #:* Haul numbers will reset for single day trips but not for multi-day trips.
– *Wind direction* can be circled if it is an estimate. Exact wind direction readings, from a computer or anemometer, should be written in the wind direction box (i.e. the wind direction is 93º).
– *Begin* and *End haul* times should be entered in 24 hour clock mode.
– *Total catch* should equal the sum of individual species estimates including yellowtail. Yellowtail weights should not be recorded as a count. If you count the number of fish, assume each one weighs 1 kg (2.2 lbs). Multiply your count by 2.2 and record in the box marked "YT Catch Estimated".
– Make any comments about torn gear, net obstructions or other observations in the *"Comments"* section.

Getting ready to tag

- During steam out of prior to tow haul back, pre-arrange the lottery tags numerically. Organizing them on a nickel pin with 50 per pin.
- Ready the tag box with the following:

– Pins
– Pink blanks and Orange scale blanks
– Lottery tags (pre-arranged numerically)
– $100 reward tags
– Data storage tags and DST oval blanks
– Rubber bands, scale envelopes, pliers, pencils and a timing device

- The chief scientist should activate enough DSTs to last for 1 day. Be sure to record the time they were activated (24 hour clock).
- Designate and record on the data sheet who will tag and record.
- Pre-fill the tagging data sheet with the heading information (Vessel name, date, etc.)
- During haul back, set up the deck in a way that is appropriate and safe based on the deck configuration.
- Set up a tagging bench or station
- Set up live well (s) and run the deck hose to fill.

Activating the Data Tags

•Hold the tag with its yellow bead thermistor to your right. The magnetic reed switch will be at the top edge of the tag.
•To begin a recording session, tap the tag at its upper right or left corner 4 times with one pole of a magnet. The four taps must occur within two seconds and the magnet must not come near the tag for the following two seconds. After each tap, move the magnet at least 2-inches away from the tag. The magnet does not need to actually touch the tag.
•The light-emitting diode (LED) will blink brightly to indicate that the tag has started. It will then blink at 14- and 15-second intervals (an average of once every 14.06 seconds), one blink corresponding to each sample that is taken.
•If the LED blinks approx. twice each second, the tag is in a rapid-recording test mode. To clear this, tap the tag 4 times with the magnet. The test mode will drain the battery more quickly than the normal recording mode.

Specifics to Fishing

•The priority is to obtain fish that are strong and healthy enough to be tagged and released in good to excellent condition (see condition ratings on page 11).
•Captain is responsible for finding concentrations of yellowtail
•Tow duration is to be short, no more than 40 minutes, to ensure small enough tows to process without undue stress and exposure to the fish. Ideal tow duration is between 15-30 minutes, depending on the area and time of day.
•If tows come up with few yellowtail and numerous skates and other species, move to another area. Bycatch, particularly skates, damage the condition of yellowtail.
•Do not begin another tow while fish are being released, even if this compromised the amount of tows that can be done per day.
•For day trips, perform 6-10 tows per day, depending on steam time and weather.
•For offshore, multi-day trips, make as many tows as possible in day light hours. Stop fishing before dusk.

Sorting the catch

•Have Captain estimate total catch (in pounds) and record on his tow data sheet.
•Choose the quickest most efficient way to isolate live yellowtail from the catch.
•With straight yellowtail tows, bag can be dumped in live well (if using a large live well).
•If the tow is mixed species, dump the tow on a wet deck.
•Gently select yellowtail from the mix and place upright in the live well (s).
•If there are enough people, have the crew isolate the yellowtail while the scientific staff begin tagging.

Tagging – I: Fish Condition

•Gloves are not required to handle the fish (it is easier to handle the fish without gloves). If gloves are preferred, use rubber gloves that will not cause scaling. If no gloves are used, make sure hands remain wet when handling fish.
•Chose a fish from the live well and assess its condition. Only tag EXCELLENT or GOOD rated fish:
–Rate the fish (1) if it is in EXCELLENT condition. Excellent fish will be lively, scale condition clean and relatively unscathed. Operculum or mouth movement may be noticeable. Fish feel robust and have strength when held against the measuring board. No blood clotting present around gills or operculum. Fish may be flapping, although yellowtail are generally calm, even when in excellent condition.
–Rate the fish (2) if it is in GOOD condition. Good condition fish are those that generally look healthy, exhibit some signs of an excellent fish. Strong body with no large abrasions of defects. Fish may have scale abrasion or net marks. Anal protrusion or slight anal tearing present.
•Fish rated (3) are in poor condition and unfit to tag. Fish is unacceptable to tag if it appears that the chance of survival is low, heavy abrasion is present, body is flaccid, and there is little movement or reaction to handling. Notate why fish is unfit to tag (i.e. “giant gash, gilled, heavily abraded” etc.) or if the fish is dead (“beheaded, torn body” etc.)

Tagging - II: Sexing

•Determine the sex of each fish. Maturity stage is not necessary to notate.
•Determine the sex by candling the fish. Hold the fish up to the sunlight and examine the ventral area of the blind side.
•Nearly all legal sized females should be mature (if tagging during the spawning season) and have a large ovary extending posteriorly from the abdominal cavity.
•Inspect the ventral area of the blind side to determine if an ovary is extending into the ventral tail meat:
- If there is darker tissue extending from the abdominal cavity toward the caudal area, code as "female."
- If the ventral and dorsal portions of the tail (posterior to the abdominal cavity) are identical in color, code as

"male."

Tagging – III: Measuring

•After the condition of the fish is deemed excellent or good, proceed to measure the fish.
•Minimize the time out of the water and handling of the fish.
•Fish size: Measure from end of snout to end of tail (to 1cm accuracy).
–Southern New England tagging areas – Tag all sub-legal (less than 33cm) fish and legal (33+ cm). Gauge the size and capability of sub-legal fish to carry a DST before applying data storage tags.
–All other tagging areas – Tagging legal fish is priority (33cm +). Tag sub-legal fish as time allows and not to detract or affect the quality or progress of tagging legal fish. Chief scientist can decide whether a fish is too small to tag.

Applying Peterson Disks - I

•Locate lateral line arch on blind side of fish. Place the pin with blank disk installed just above the middle of line arch. Puncture the fish.

•Make smooth, clean puncture at a perpendicular angle to fish body until blank is flush with blind side.

Applying Peterson Disks -II

•Place pink disk (with side labeled "Call toll free 1-877-826-2612…") facing away from fish on nickel pin, flush with fish body.

•To trim the pin, place needle-nose pliers slightly above flush with tag, cutting edge up and trim the pin. There should be about 1 inch of pin left once trimmed.

•Grab the end of pin with the tips of needle nose pliers. Crimp pin in a U-shape. Close gap between crimp tightly. Crimp should measure approx. 3 mm.

•Bend crimp over with pliers so it's at a perpendicular angle to the post of the pin (parallel to the fish body). Insure there is space between tag and bend (approx. 3-4 mm, depending of fish size) to allow room for growth. For sub-legal fish, allow approx. 12-24 mm for growth, depending on fish size.

Applying Peterson Disk - III

•Release fish immediately if it remains lively. If not, allow a minute or so of recovery in the live well before release.

•Release the fish head first to minimize re-orientation and time in warm surface waters.

•If you get a left-eyed yellowtail, treat and tag the same as right-eyed fish. Notate in comments on tagging data sheet.

Applying Data Tags – I

•What you will need: 1) Activated data tags, 2) pink oval backing tags, 3) nickel pins, two per tag, 4) pliers, 5) tweezers for taking scales, and 6) scale envelopes.
•Make sure the tag has been activated by watching for a red flash on the tag. If activated during the trip, the flash should be every 15 seconds to 1 minute.
•Data tags are applied using 2, 3" nickel pins (instead of the 1 used for disk tagging).
•Ready the oval backing tags by placing a pin in one end. Make sure the labeled side will be facing out.
•Align the oval blank similarly to the disk tag, above and centered to the lateral line arch.
•Insert the first pin at a perpendicular angle to the fish body. This is very important in aligning the tag correctly over the pins.
•When the pin and oval disk are in place, insert the second pin, getting the two pins as parallel as possible to each other.
•Fit the data tag, return address label up, over the pins.

Applying Data Tags - II

•Trim the pins one at a time. Place the needle-nose pliers slightly above flush with tag, cutting edge up and trim. There should be about 1 inch of pin left once trimmed.
•Grab the end of pin with the tips of needle nose pliers. Crimp pin in a U-shape. Close gap between crimp tightly.

Crimp should measure approx. 3 mm.
•Bend crimp over with pliers so it's at a perpendicular angle to the post of the pin (parallel to the fish body). Insure there is space between tag and bend (approx. 3-4 mm, depending of fish size) to allow room for growth.
•For sub-legal fish, chief scientist will decide whether the fish is big enough to carry a data tag. If tagging, allow approx. 12-24 mm for growth, depending on fish size.
•Be sure to record the time when the fish is released for every data tag deployed.

Getting Scale samples

•Scale samples are to be collected for the following fish:
–All $100 tags
–All data tags
–$1000 lottery tags that are applied with orange or pink scale sample backing tags.
•Chief scientist will decide how many scale samples to collect.
•Generally, taking scales from at the beginning of each tagging session is helpful in assuring scales are collected from fish in the best condition.
•Only take scales from fish in excellent condition.
•If taking scales will compromise fish health, take scales from next fish.
•Pluck 5-10 scales using forceps from just above the lateral line, approx. midway on body of fish.
•Place scales in a small envelope and label with the station information, date, sex and length of the fish.
•Record any comments on the data sheet.

Filling out the tagging data sheet

•Paper is "Right in the Rain" water-resistant.
•Trip ID and Haul #: (refer to page 7, ("Filling out the Captain's Log").
•Each tagger will have a pre-arranged set of tags on nickel pins. The tag numbers to be used will be recorded at the beginning of the haul for each tagger and modified at the end of the haul after all the fish have been tagged.
•Record the number of live and dead discards.
•Note the condition of the fish. There are 2 categories, "trawl damage" and "biological comments". Check all that apply to the fish being tagged.
•Make any additional comments in the "Comments" field to the far right.
•Be sure to record the page numbers and all heading information on each sheet used. Each 2-sided sheet is considered one page and given the same number.
•The recorder must tally the total fish tagged and discarded at the end of the tagging session.

Recapturing a tagged fish

•Remove the tag from ALL recaptured fish. Do not re-use the tag.
•Treat each fish as a recapture and record (if from a previous trip) and location. Take scales from high reward, DST's and scale-labeled blanks. Use the tag recapture phone sheets to record the information.
•Tag number
•Date
•Latitude/Longitude
•Length (if the fish was released on a separate trip)
•Make any observations about the tag wound area and health of the fish.
•In the "Reported By:" category, write "T" which stands for "Tagging cruise"
•If there are a large number of recaptures from the same day or trip, move to a new fishing spot.