Impact on Recreational Fishing of Mycobacteriosis in Striped Bass: What is the fate of infected fish?

Final Report

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Summary

1) The prevalence of mycobacterial skin disease is estimated to have been 69% in the upper Rappahannock River (river mile 46) and 73% at the mouth of the river in the fall of 2005.

2) The prevalence of visceral (splenic) mycobacterial disease is estimated to have been 77% and 79% at the up-river site and mouth, respectively in the fall of 2005.

3) The presence of skin lesions (pigmented foci or ulcerous lesions) appear to have high positive predictive value for visceral (splenic) disease. However, the absence of skin lesions is not a good predictor of lack of visceral disease.

4) A cooperative tagging program was established with VIMS tagging striped bass in the Rappahannock River and sport fishers returning tags upon recapture of fish. Numerous contacts were made with sport fishing groups, interviews were given to local news media, and presentations were made to sport fishing groups to publicize the program. Over 1800 fish were tagged and 136 recaptures were obtained.

5) Comparison of photos of fish at the time of tagging and at the time of recapture demonstrate slight progression of the disease over the winter months. Examination of tagged fish that have been at liberty over the summer will shed information on disease progression during the warmest months of the year.

6) We tagged 1,809 fish in the Rappahannock River and photographed each fish prior to release. Tags from 136 fish were recovered from fishers. Diseased fish had a higher recapture rate than fish without lesions, suggesting that diseased fish may not move as much as non-diseased fish.

7) The simple estimator of relative survival rate described by Hueter et al. (2006) does not appear to be suitable for studying the effects of mycobacteriosis because diseased fish appear to be more catchable than non-diseased fish. Therefore, alternative models described by Brownie et al. (1985) and Hoenig et al. (2006) will be utilized.

8) Managers and scientists in various jurisdictions have been informed of the goals and progress of the project through presentations at scientific meetings and a stock assessment forum.

This project has five objectives: 1) Initiate a cooperative program to enlist the aid of sport fishers in recovery of tagged fish in order to estimate survival rates in relation to disease status, 2) determine the rate of progression of dermal and visceral mycobacteriosis, and mortality rates, in striped bass held in a large holding pen under field conditions, 3) estimate the relative survival of fish with and without *external clinical signs* of mycobacteriosis by tagging and releasing fish with and without skin lesions, and having sport fishers return tags, 4) convey the results of this study to fishers, management agencies, and funding bodies so that informed striped bass management decisions can be made, and 5) if the project is continued for a second year, an additional objective will be possible: develop and apply a model to tagging data to estimate survival of fish with and without visceral (internal) mycobacteriosis.

Objective (1) – cooperative program.

To initiate the cooperative program with sport fishers, Vogelbein made a presentation to the Virginia Marine Resources Commission about the mycobacteriosis problem. We asked the Commission to allow sport fishers to possess our specially tagged striped bass with green tags without regard to size, season or bag limits so that the sport fishers could provide information on tagged fish to us. The Commission agreed and made possession of green-tagged striped bass exempt from such regulations. We then produced and distributed 1000 brochures explaining about mycobacterial disease in striped bass and explaining our research project. These brochures were distributed to fishing clubs, bait and tackle shops and other interested parties. In addition, Wolfgang Vobelbein made presentations to various sport fishing groups and media outlets including those listed below.

Vogelbein. Invited guest speaker Annual Banquet of the Coastal Conservation Association. Richmond, VA. 22 March, 2006. Title "Mycobacteriosis, an emerging disease in the striped bass: Recreational fisherman participation in a new tagging program at VIMS".

Vogelbein. Presented and distributed striped bass disease informational brochures at the monthly meeting of the Deltaville Chapter of the Coastal Conservation Association.

Vogelbein. Attended the Dec. 7, 2005, Deltaville Rockfish tournament. Distributed informational brochures and spoke at two Captain's meetings. Was present during day of tournament to examine tagged fish.

Vogelbein. Interviewed with Don Lancaster on the "Fishing Tidewater" show on WLRT, 1490 AM radio to educate local recreational fishermen about this striped bass research program.

Vogelbein. Interviewed with Elizabeth Shogren of National Public Radio (NPR) regarding the state of striped bass health in the Bay and ongoing projects to better understand the impact of mycobacteriosis on the striped bass population.

Preparation for Objectives (2) and (3)

Characterization of fish. In order to monitor disease progression and quantify effects of disease on fish survival, we needed to characterize the appearance of diseased fish. We looked at four external characters:

scale damage (erosion)
pigmented foci
ulcerous lesions
hyperpigmented areas consistent with healing (putative healing).

Fish without any of the above symptoms were designated as "clean". Histological examination of fish with the above characters confirmed that fish with pigmented foci and ulcerous lesions were almost always associated with granulomas with acid-fast bacteria in the dermis. Hence, these characters appear to be clear indications of mycobacterial disease. In contrast, the presence of scale damage and hyperpigmented areas do not appear to be strongly linked to the presence of histologically demonstrable mycobacterial disease. Consequently, we restrict our attention to the pigmented focus and ulcerous lesion characters. For the two characters, a severity rating was made as follows:

pigmented focus (PF), approximately 1 mm dark focus:

Severity	description
1	light: 1 – 10 foci
2	moderate: 11-50 foci
3	heavy: 51 or more foci

ulcerous legion (U):

Severity	description
1	focal, lesion < 2 cm^2
2	multifocal, all lesions < 2 cm^2
3	focal, lesion > 2 cm^2
4	multifocal, some lesions > 2 cm^2

We defined disease categories as follows:

clean:	no external signs of disease
light:	fish with PF1 or U1 or both
medium:	fish with PF2 or U2 or both
heavy:	PF3 and/or either U3 or U4
other:	fish with scale damage or signs of putative healing or both

Note that in the above classification scheme, fish classified as light, medium or heavy may have scale damage or signs of putative healing or both.

Prevalence. We obtained 336 fish from commercial pound nets in the upper Rappahannock River (river miles 45 to 47). All fish were examined externally for signs of disease. The composition of the fish was as follows:

category	number	estimated prevalence (%)
no lesions (clean)	89	26
light	155	46
medium	60	18
heavy	18	5
other	14	4

Prevalence of a category is defined as the percentage of the population falling in that category. Overall prevalence of skin disease (light + medium + heavy) was 69%

A stratified subsampling scheme based on the above disease categories was used to obtain fish for examination of the spleen by histological means. The results of the histological investigations are shown in Table 1a.

We also collected 1662 fish from commercial pound nets at the mouth of the Rappahannock River (river miles 0 to 2). The composition of the fish was as follows:

category	number	estimated prevalence (%)
no lesions (clean)	380	23
light	774	47
medium	310	19
heavy	137	8
other	61	4

Overall prevalence of skin disease (light + medium + heavy) was estimated to be 73%. Results of histological examination of subsamples are shown in Table 1b.

From these data, we can estimate the positive predictive value (PPV) and negative predictive value (NPV) of skin lesions for predicting the presence of visceral (splenic) mycobacterial disease. Positive predictive value is the probability a fish has splenic disease given that it has specified signs of skin disease. Mathematically,

PPV = # fish with splenic disease and have specified signs of skin disease / # fish with specified signs of skin disease

Negative predictive value is the probability a fish does not have splenic disease given that it does not have particular signs of skin disease. Mathematically,

NPV = # fish without splenic disease and without specified signs of skin disease/ # fish without specified signs skin disease

The positive and negative predictive values of skin disease categories for splenic disease are given in Table 1. Clearly, the positive predictive values are quite high, meaning that a fish with any kind of external sign of mycobacterial disease is highly likely to also have visceral disease. Note that the negative predictive values are quite low which mean that a fish without any external signs of mycobacterial disease is still highly likely to have visceral disease. PPV and NPV are not independent of the prevalence of visceral disease. Thus, the low value of NPV reflects the high prevalence of visceral mycobacterial disease (see below).

From the data in Table 1 we can compute the prevalence of visceral (splenic) mycobacterial disease using the following relationship:

$\Pr(\text{visceral disease}) = \Sigma_a \Pr(\text{visceral disease} \mid \text{skin category a}) \times \Pr(\text{skin category a})$.

Here, Pr( ) refers to the probability of the event in the parentheses occurring, the | symbol is read as "given that the following occurs", and Σ_a means the sum over all the categories "a". The estimated prevalence of splenic disease is thus found to be 77% for the upper river site and 79% for the mouth of the river.

From the data in Table 1 we can also compute the sensitivity and specificity of using skin characters to predict visceral disease. Sensitivity is probability a particular sign of disease appears in the skin given that the fish has visceral disease. Specificity is probability a fish does not show a particular sign of disease in the skin given that the fish does not have visceral disease.

Objective (2) – holding pen studies.

We procured, tested, modified and deployed a 16' by 16' holding pen with an 8' deep pocket at the upper Rappahannock River site (Figure 1). A second holding pen was acquired using funds from another grant. We were able to obtain sufficient baitfish to feed the bass by trawling. Although we were able to hold some fish for up to 12 weeks, the results were extremely disappointing because many of both the control and diseased fish developed massive bacterial or fungal infections externally and had high mortality. This is perplexing because we have previously held striped bass under similar water temperatures at the same site in much smaller holding pens. We believe we will have much better success when we repeat the study at the mouth of the Rappahannock River where salinity is higher because low salinity can stress striped bass.

Objective (3) – tagging studies to estimate relative survival rates.

We tagged 246 fish at the upriver site and 1563 fish at the mouth. The breakdown of the fish tagged and fish recovered by disease category is shown in Table 2. All fish were examined externally for signs of mycobacterial skin disease, their condition was noted, and a photograph of each side was taken prior to releasing the fish.

Disease progression. We obtained 130 recaptured fish from fishers who kept the fish on ice for us until they could be picked up. (This includes fish tagged in the fall of 2005 and the spring of 2006; 92 of the carcasses were from fish tagged in the fall of 2005). Most of those fish were short-term recaptures and showed no progression of the disease. However, 10 fish were at liberty for over one month. Before and after photos for four fish show slight progression of the disease over the winter (Figures 2 to 4). One hypothesis is that appearance and growth of lesions is enhanced by stress caused by elevated water temperatures. Thus, further recaptures this fall will be important for evaluating this hypothesis.

Analysis of tag returns. We obtained 19 tag returns from fish tagged upriver and 117 returns from fish tagged at the mouth (Table 2). While these are good numbers of tag recoveries, the data present a problem for the estimation of relative survival rates of the different disease categories. Assuming equal catchability and equal tag reporting rates across all disease categories, the change in the ratio of number of recaptures from two disease categories provides an estimate of the ratio of survival rates (Hueter et al. 2006). This can be demonstrated as follows. Suppose n_a fish in skin category a are tagged and released and these experience a survival rate S_a. Suppose further that n_b fish in skin category b are tagged and released and they experience survival rate S_b. Then after t units of time, the ratio of tag returns will be

$$\text{ratio of returns } (a{:}b) \text{ at time } t = r_t = \frac{n_a S_a^t}{n_b S_b^t}.$$

Therefore, after one unit of time, the ratio of survival rates can be estimated as $n_b\, r_t / n_a$. More generally, the ratio of survival rates can be estimated by regressing the ratio on time at liberty.

The problem is that a greater proportion of diseased fish were recaptured than clean fish in both the fall and the spring. One explanation is that diseased fish move less than clean fish and thus are more likely to be recaptured in the pound nets at the mouth of the Rappahannock. (The pound nets account for much of the recaptures.) If confirmed, this change in migratory behavior and movements associated with disease is an important finding with implications for fish feeding and for the ability of fish to avoid stressful environments by searching for favorable habitats. We are investigating the distances between release and recapture locations.

In terms of quantifying the impact of the disease through estimation of relative survival rates, the findings that diseased fish have a higher recapture rate implies that alternative models must be used. Thus, we plan to use Brownie models (Brownie et al. 1985) or instantaneous rates models (Hoenig et al. 1998a,b) to estimate survival rates of diseased and clean fish separately.

Objective (4) – conveying results to fishers, managers and funding agencies .

Vogelbein. Invited guest speaker Annual Banquet of the Coastal Conservation Association. Richmond, VA. 22 March, 2006. Title "Mycobacteriosis, an emerging disease in the striped bass: Recreational fisherman participation in a new tagging program at VIMS".

Vogelbein. Invited: NOAA Chesapeake Bay Office annual meeting. Williamsburg, VA. 26 April, 2006. Title "Mycobacteriosis in Chesapeake bay striped bass: The fate of infected fish".

USGS/NOAA Mycobacteriosis in striped bass Workshop. Annapolis, MD, 9-11 May, 2006

1 Gauthier, Latour and Vogelbein. "Epizootiology of mycobacteriosis in Chesapeake Bay striped bass (Morone saxatilis): large-scale field survey".

2. Vogelbein, Hoenig and Gauthier. "Mycobacteriosis in Chesapeake Bay striped bass: What is the fate of infected fish?"

Voglebein. AQUAMED Summer calls in fish health issues. Louisiana State University School of Veterinary Medicine

lecture: "Mycobacteriosis in Chesapeake Bay striped Bass".

Vogelbein. Presented and distributed striped bass disease informational brochures at the monthly meeting of the Deltaville Chapter of the Coastal Conservation Association.

Vogelbein. Attended the Dec. 7, 2005, Deltaville Rockfish tournament. Distributed informational brochures and spoke at two Captain's meetings. Was present during day of tournament to examine tagged fish.

Vogelbein. Interviewed with Don Lancaster on the "Fishing Tidewater" show on WLRT, 1490 AM radio to educate local recreational fishermen about this striped bass research program.

Vogelbein. Presented to the full Marine Resources Commission describing the current disease status of Chesapeake Bay striped bass and the VMRC-funded disease research project presently underway.

Vogelbein. Interviewed with Elizabeth Shogren of National Public Radio (NPR) regarding the state of striped bass health in the Bay and ongoing projects to better understand the impact of mycobacteriosis on the striped bass population.

Vogelbein and Gauthier wrote a press release on the mycobacteriosis problem for local newspapers.

Hoenig has presented results to Atlantic States Marine Fisheries Commission Striped Bass Tagging Subcommittee
Results and proposals for research have been presented to Virginia Sea Grant, NOAA Chesapeake Bay Office, Virginia Commercial License Fund, and National Science Foundation / National Institutes of Health Ecology of Infectious Diseases program.

Further efforts will be made to convey results, especially to sport fishers, as analyses are completed and information accrues.

Objective (5) (for year 2) – develop further tagging models

Consideration of funding for the second year of the project has been deferred by the Recreational Fishing Advisory Board. Alternative funding from the National Oceanic and Atmospheric Administration has been received so tagging efforts and development of models will continue in year two and subsequent years.

Literature Cited

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Hoenig, J.M., N.J. Barrowman, W.S. Hearn, and K.H. Pollock. 1998. Multiyear Tagging Studies Incorporating Fishing Effort Data. Can. J. Fish. Aquat. Sci. 55:1466-1476.

Hoenig, J.M., N.J. Barrowman, K.H. Pollock, E.N. Brooks, W.S. Hearn and T. Polacheck. 1998. Models for Tagging Data that Allow for Incomplete Mixing of Newly Tagged Animals. Can. J. Fish. Aquat. Sci. 55:1477-1483.

Hueter, R.E., C.A. Manire, J. Tyminski, J.M. Hoenig and D.A. Hepworth. 2006. Assessing Mortality of Released or Discarded Fish Using a Logistic Model of Relative Survival Derived from Tagging Data. Trans. Am. Fish. Soc. 135:500-508.

Table 1. Results of macroscopic examination of skin and histological examination of spleens from a subsample of fish from the Rappahannock River. Table entries are numbers of fish. Note that the numbers examined in each category of skin appearance were fixed by the investigators. (a) the upriver site; (b) mouth of the river.

(a) upriver site

appearance of skin	histological results positive	negative	PPV	NPV
clean	16	10	----	.38
light	29	8	.78	----
moderate	12	1	.92	----
heavy	8	0	1.00	----
other	4	2	.67	----

(b) mouth of the river

Appearance of skin	histological results positive	negative	PPV	NPV
clean	25	10	----	.29
light	16	4	.80	----
moderate	12	1	.92	----
heavy	31	0	1.00	----
other	0	0	----	----

Table 2. Summary of fish tagged in the Rappahannock River in the fall of 2005 and the recaptures to date. Table entries are numbers of fish. (a) the upriver site; (b) mouth of the river.

(a) upriver site

	number	number recaptured in	
skin category	tagged	fall 2005	winter 2006
clean	63	2	2
light	118	9	1
moderate	47	3	1
heavy	10	1	0
other	8	0	0

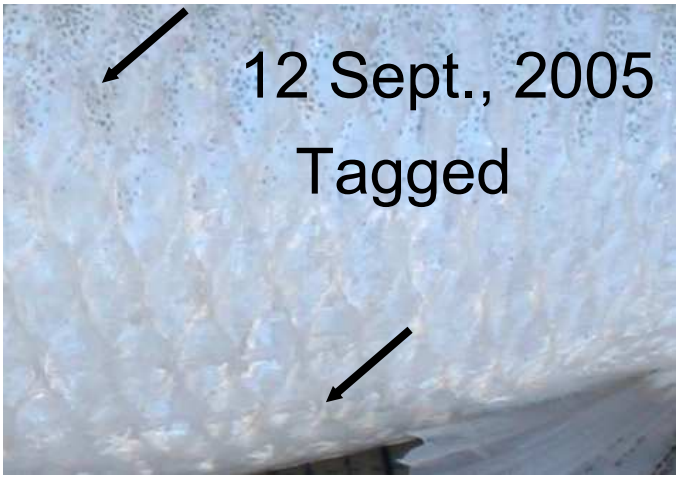
(b) mouth of the Rappahannock

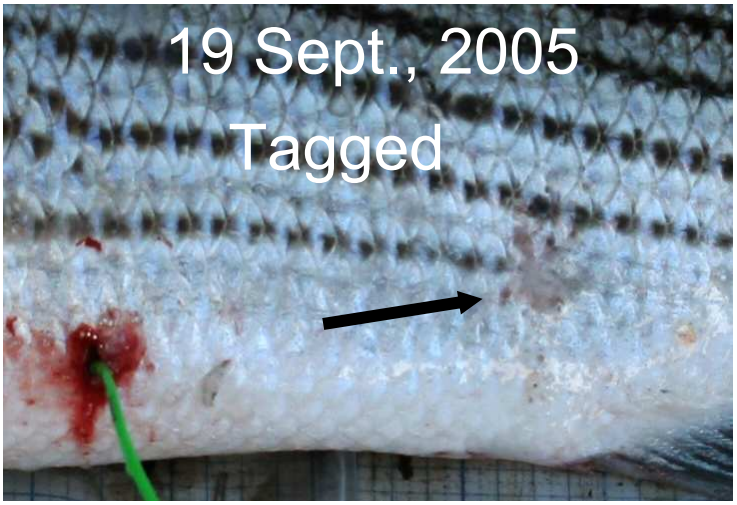
	number	number recaptured in	
skin category	tagged	fall 2005	winter 2006
clean	345	15	1
light	754	47	7
moderate	297	27	4
heavy	106	11	2
other	61	2	1

Figure 1. Holding pen constructed for disease progression and survival rate studies. Note the floating cover inside the pen to prevent loss of fish.

Figure 2. Pigmented foci from the skin of a striped bass released 29 Sept. 2005, and recaptured 6 April 2006. Pigmented foci present on both dates appear more erosive upon recapture. Some pigmented foci (white arrows) have disappeared during the 6 mo. between pictures, whereas some new pigmented foci (black arrows) have appeared.

Figure 3. Recaptured fish at the left has developed numerous additional pigmented foci not present at tagging (arrows). The fish on the right had a lesion at the time of tagging that does not appear to have changed much over the course of the fall and winter; however, additional pigmented foci have appeared.





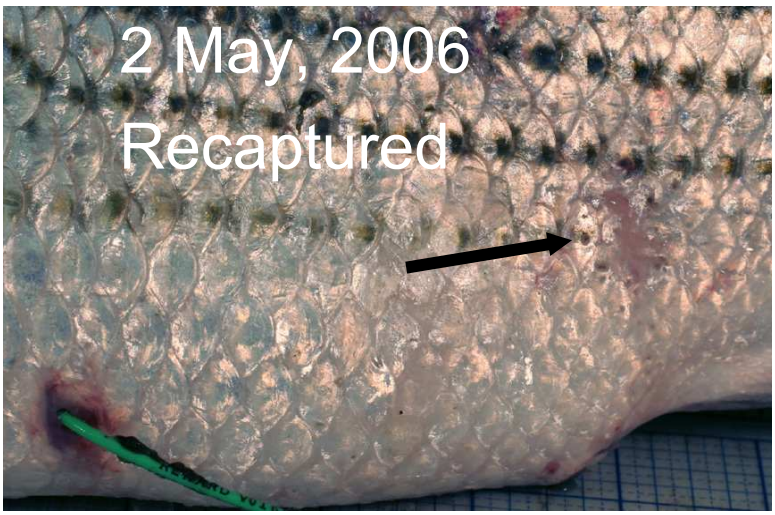


Figure 4. Bilateral ulcerative lesions in fish tagged 27 Oct. 2005 and recaptured 12 June 2006. Ventral lesion (left pictures) has expanded, and apparent granulation tissue has formed over a portion of the ulcer. Dorsal lesion (right pictures) has expanded, and a pigmented zone has appeared within the lesion margin, possibly indicating re-epithelialization and scale regeneration.