Fisheries

VOL 35 NO 3
MARCH 2010

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Defining Overfished Stocks: Have We Lost The Plot?

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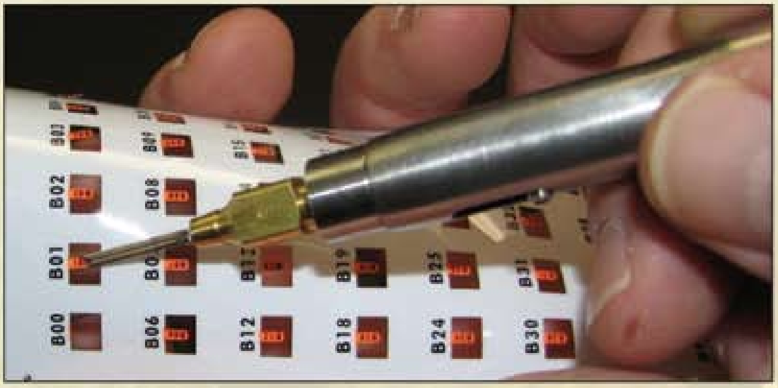

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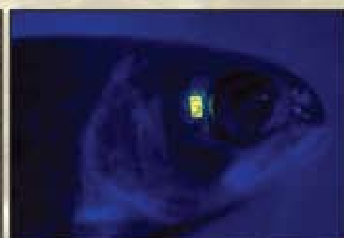

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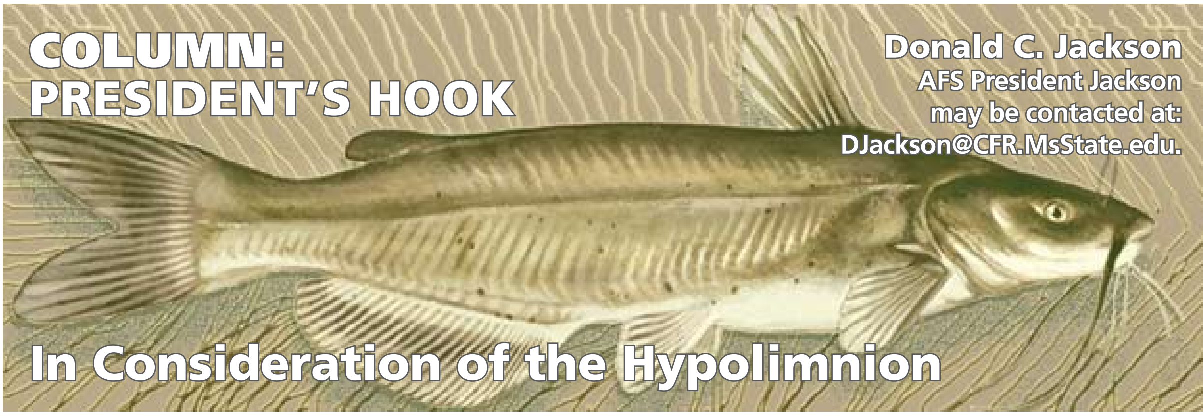

COLUMN: PRESIDENT'S HOOK

Donald C. Jackson
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In Consideration of the Hypolimnion

The governor of a southern U.S. state made a comment during a press conference a few months ago regarding the economic recession. He said that his state really isn't impacted as much by the recession as are other states because it didn't have as far to fall. As a native son and resident of the Deep South, I had to admit that there was a lot of truth to what the governor said. We are most certainly hurting down here but I don't think we're hurting as much as are people elsewhere. It is a matter of relativity…and perspective.

There are many different economies in the Deep South, with the money economy just being one of them. Down here, we tend to define wealth and prosperity in terms that transcend pay checks, cash flow, investments, and dividends. It has more to do with a state of mind than anything else. I gauge the state of the economy in my part of the world by the amount of trash I see along the highways and by the way houses out in the countryside look. As the money economy tightens, the roadsides are a whole lot cleaner, houses get fresh coats of paint, wood piles are stacked neater, pickup trucks (and even tractors!) are washed, gardens have fewer weeds, and screen doors are repaired. Folks just don't move around as much when the money economy "goes south," they don't buy as many things that get thrown out of car windows, and they spend more time at home and with family. It seems to me that the grades kids earn in our public schools have tended to improve during this recession. Perhaps parents (myself included) are spending more time in the evenings with their youngn's. It also seems to me that students at the university where I teach are sticking closer to campus and are more involved in campus life—certainly not a bad thing.

I am writing this on the last weekend of the duck hunting season in Mississippi. Although it is only a little after 8:00 a.m., I've already been to the woods, hunted ducks in a little brushy pond tucked away in a quiet corner of my 50-acre farm, listened to the whistle of stiff wings overhead and the calls of barred owls and Canada geese, felt the vigor of a cool northwest wind, watched dawn brush the landscape, and connected with the rhythms of the earth and to dimensions beyond. My morning rambles on the farm, before the day becomes all hustle and bustle, are precious to me.

I am a consumptive user of natural resources. I go to my farm to nurture body as well as spirit. Each year, during early fall, I typically take a couple of deer from the place. In addition to deer and ducks, I also hunt squirrel, rabbit, dove, and occasionally raccoon. My family rarely buys meat. Out on the edge of one of my pastures I have a pond that I manage specifically for large bluegill (*Lepomis macrochirus*) by keeping it slightly overcrowded with largemouth bass (*Micropterus salmoides*). Once hunting seasons are over, my focus turns to this pond and to the fishing it provides. Ten-inch long bluegills are treasures on a 2-weight fly rod. In my home I have a wood burning stove that I fuel with seasoned oak that I cut from my woods. I manage for sustainability. I nurture the land and its resources. They respond in beautiful ways. Our relationships are synergistic and have endured (or more correctly…prospered) for many years. The combination of science with art and a sense of moderation works.

My lifestyle is very common in the South. For me it is by choice. But I am surrounded by people whose engagement in such a lifestyle is not by choice. Fishing, hunting, cutting wood for a stove, gardening, and perhaps tending a small flock of chickens and sharing with a neighbor an investment in a hog or a steer each year are endeavors that keep them afloat. They drift into and out of employment as the dynamics of local economies wax and wane. Their security, such as it might be, is associated with the land and the water…and with each other.

In the fisheries sector, the trotlines, nets, and—further south, down in our coastal marshes and bays—crab pots are frequently not out there in the water for recreational or commercial purposes. The woman sitting on a bucket beside a stream or a ditch below a bridge, cane pole in hand, is very likely not doing this for fun. Neither are the children with her. Neither are the people who are fishing in a small impoundment located on my university's campus, or the guy with a cast net working the shallows of a back bay near Biloxi. These fisheries also tend to be non-discriminatory with respect to targeted species. Buffaloes (*Ictiobus* spp.) and other catostomids, gars (*Lepisosteous* spp.), catfishes (Ictaluridae) of all sorts, mullets (*Mugil* spp.), an assortment of drums (Sciaenidae), a full suite of sunfishes (Centrarchidae), blue crab (*Callinectes sapidus*), and even

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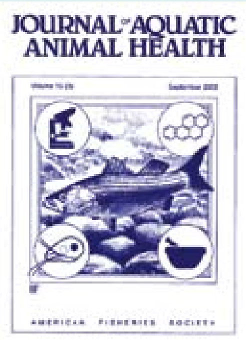

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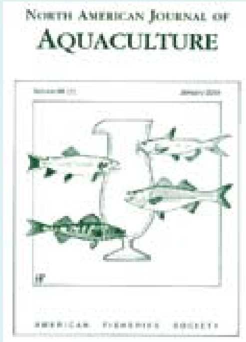

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UPDATE: LEGISLATION AND POLICY

Elden Hawkes, Jr.

AFS Policy Coordinator Hawkes can be contacted at ehawkes@fisheries.org.

Briefing on National Fish Habitat Conservation Act rescheduled

On 16 March 2010, the American Fisheries Society (AFS) will hold a briefing in H.R. 2656, the "National Fish Habitat Conservation Act," and the National Fish Habitat Action Plan. Originally scheduled for 10 February 2010, but postponed due to weather issues, the briefing is being presented in partnership with various organizations including the Association of Fish and Wildlife Agencies, U.S. Fish and Wildlife Service, and the National Fish Habitat Board. The briefing will emphasize the importance of the bill and showcase how vital U.S. fish habitats are to the stability of our ecosystem and our country as a whole. The briefing will be held in room B-339 of the Rayburn House Office Building at 8:30 a.m.

San Clemente Dam to be removed

The National Oceanic and Atmospheric Administration (NOAA) has joined California state and local officials in a pledge to remove the San Clemente Dam. The dam removal will aid in the recovery of steelhead trout by opening up access to more than 25 miles^2 of spawning and rearing habitat. Steelhead in the Carmel River were listed as threatened under the Endangered Species Act in 1997.

The 89-year old, 106-foot high dam, which once helped bring water to residents of Monterey County, is at risk of failing during a significant earthquake or flood. Sediment has been building up behind the dam for years, making it a hazard for those living below it and almost useless as a water storage reservoir. If the dam were to fail, an estimated 2½ million cubic yards of sediment and more than 40 million gallons of water could rush downstream with potentially disastrous consequences.

Italy moves to ban bluefin tuna fishing for one year

The European Union (EU) has announced that Italy will discontinue the fishing of bluefin tuna for a period of 12 months. Such a drastic move will sideline the Italian fleet, which contains 49 trawlers and 700 fishermen. Financially, the decision is enabled by financial aid from Brussels, which will offset the losses incurred by the ban. As a result of the voluntary ban, France has called for an 18-month international ban, while the European Union has proposed a non-time specific ban of bluefish tuna. All efforts are seen as a way to allow the world's remaining stocks of bluefin tuna to be replenished.

NMFS Revises Black Sea Bass Quotas for 2010

NOAA Marine Fisheries Service (NMFS) has published a temporary rule to implement the revised quotas to the 2010 black sea bass harvest. The catch recommendation has been increased from 2.71 million pounds to 4.5 million pounds. This increase corresponds to the catch levels established in 2008. Black sea bass is not overfished nor is overfishing occurring. The increased catch levels are expected to alleviate the social and economic impacts of the previously announced catch recommendation.

Deal Reached Between EU and Norway on fisheries quotas

A final agreement was reached in fisheries talks between the European Union and Norway. The two parties agreed on a 10-year management plan for the mackerel stock (starting in 2011), which will include a 5% decrease in total allowable catches (TAC) for 2010. They also agreed on the seven jointly managed stocks, with TACs set in accordance with the stocks' science and managements plans. This includes a 16% increase in cod, and 15% decreases in haddock and whiting. Agreements were also reached on stocks jointly managed with Norway, including Scotland's whitefish fleet; cod, haddock, and whiting in the North Sea; and on the balance of fish transferred every year between the EU and Norway.

PERSPECTIVE:
FISHERIES MANAGEMENT

Defining Overfished Stocks: Have We Lost The Plot?

Ray Hilborn and Kevin Stokes

Hilborn is a professor in the School of Aquatic and Fishery Sciences at the University of Washington, Seattle, and can be contacted at rayh@uw.edu. Stokes is is a private consultant based in Wellington, New Zealand.

ABSTRACT: In recent years, there has been increasing emphasis on prevention of overfishing and agencies such as the National Oceanic and Atmospheric Administration now report the proportion of stocks that are overfished as a primary indicator of the agencies' performance. Almost all national and international legislation makes specific reference to maximum sustainable yield (MSY) and most definitions of overfishing are related in some way to achievement of MSY. We show that many of the definitions of overfishing now being adopted by fisheries agencies are increasingly unrelated to achievement of MSY and have become, to a great extent, arbitrary. We argue that overfishing definitions and management targets are generally better based on levels of historical stock size rather than the growing trend to setting targets in relation to theoretical unfished stock sizes.

Definiendo stocks sobrepescados: ¿se ha perdido el argumento?

RESUMEN: Recientemente se le ha dado especial énfasis a la prevención de la sobrepesca y agencias como la Nacional de Administración Oceánica y Atmosférica reportan como su principal indicador de desempeño, la proporción de stocks sobreexplotados. Casi toda la legislación existente, nacional e internacional, hace referencia específica al Rendimiento Máximo Sostenible (RMS) y la mayor parte de las definiciones de sobrepesca se relacionan de alguna forma a la adquisición de dicho nivel de rendimiento. En la presente contribución se muestra que muchas de las definiciones de sobrepesca que adoptan las agencias de pesquerías, se alejan cada vez más del nivel de RMS y que se han convertido, en buena medida, en algo arbitrario. Se discute que las definiciones de sobrepesca y objetivos de manejo generalmente tienen una mejor base en los niveles históricos del tamaño del stock que en la tendencia creciente de establecerlos en relación al tamaño teórico del stock en estado virgen.

While concern about overfished stocks has long been an important issue in fisheries management, in the last decade this concern has become institutionalized so that now many agencies report on the portion of their stocks that are overfished or depleted. In the United States in 2006, 25% of 187 stocks that were assessed were classified as overfished. (NMFS 2006). Closely related to definitions of "overfished" is the concept of the biomass that produces maximum sustainable yield (BMSY) and MSY. BMSY has become central to the definitions of reference points for fisheries management, which are now widely considered an essential part of well-managed fisheries. The term "overfished" is usually used to refer to a low level of stock abundance, and "overfishing" to high exploitation rates.

In this article, we review the scientific analysis and the legislative history of concern about overfishing and show that the current standards adopted in many jurisdictions have little if any basis in the science or the legislation. We suggest that many stocks now (or potentially) classified as overfished, depleted, or collapsed are producing at very close to their maximum sustainable yield and meeting the intent of national and international legislation. Agencies need to carefully distinguish between stocks that are at low abundance, and stocks that are fished so hard that their sustainable yield is significantly reduced.

Most national and international fisheries legislation makes specific reference to maximum sustainable yield. For example the United Nations Convention on Law of the Sea (UNCLOS) provided the template for much current legislation, and makes explicit mention of "levels which can produce the maximum sustainable yield," which is commonly expressed as BMSY.

> Such measures shall also be designed to maintain or restore populations of harvested species at levels which can produce the maximum sustainable yield, as qualified by relevant environmental and economic factors, including the economic needs of coastal fishing communities and the special requirements of developing States, and taking into account fishing patterns, the interdependence of stocks and any generally recommended international minimum standards, whether subregional, regional or global. (UNCLOS Article 61.3)

The underlying theory of MSY and BMSY emerged in the 1930s with the work of Russell (1931), Hjort et al. (1933), Graham (1935), and others, and was codified in the classic books of the 1950s by Beverton and Holt (1957) and by Ricker (1958). Most commonly the potential sustainable yield (or surplus production) can be related to either the fishing mortality rate, or the stock size in "yield curves" as shown in Figure 1.

Emerging from these two yield curves are the three key concepts around maximum sustainable yield, the MSY itself, the biomass that produces MSY (BMSY) , and the fishing mortality rate that produces MSY (FMSY). The prescription for maximizing fisheries was quite simple—either hold the stock size at or around BMSY, or the fishing mortality rate at FMSY.

By the 1960s, MSY was a key element of the basic science of fisheries management.

> The basic idea was enshrined in national policy documents, incorporated in international treaties, and, in effect, became synonymous in most people's minds with sound management. Most fishery managers and politicians engaged in a steady dialogue of explaining why they had to compromise a bit on MSY for "social reasons" but, in so doing, they usually sounded apologetic. They knew they were sinning. (Larkin 1977:2)

They were "sinning" because they were allowing the fish stocks to be at biomasses that produced less surplus production than would be produced at BMSY. The "sin" was a loss in surplus production.

At the same time that the basic precepts of MSY were being incorporated in national policy and international treaty, the science was moving on, recognizing the varied objectives and complexities of management, leading to a "requiem for MSY" (Larkin 1977), and a call for "optimal yield" rather than maximum sustained yield (Roedel 1975). In the 1980s John Gulland prepared a not too tongue-in-cheek definition of MSY as:

> A quantity that has been shown by biologists not to exist, and by economists to be misleading if it did exist. The key to modern fisheries management. (John Gulland, pers. comm.)

Punt and Smith (2001) recount the death, crucifixion, and final resurrection of MSY in the 1990s as organizations sought to come to grips with the legislation they had inherited from the religion of MSY generated in the 1950s. It has certainly long been recognized that what may be overfished from one perspective may be well managed from another (Cunningham and Whitmarsh 1981) .

In each jurisdiction, management agencies have attempted to provide operational definitions of legislation in which MSY, BMSY, and/or FMSY have become enshrined. In the United States, the governing legislation is the Magnuson-Stevens Fisheries Management and Conservation Act (2007), which specifies:

> (1) Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.

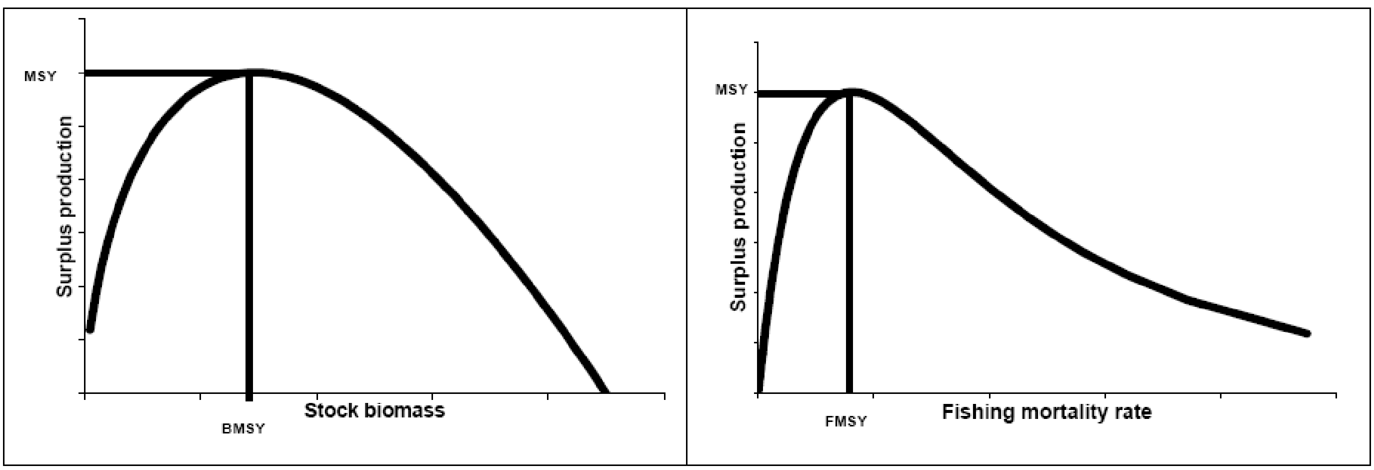
Here we see the clear intent to prevent the loss of yield due to overfishing. However there needs to be an operational definition and this is provided in the NOAA "National Standard Guidelines" (NOAA 2005:36251)

> (xxi) MSY stock size (BMSY) means the long-term average stock abundance level of the core stock or stock assemblage, measured in terms of spawning biomass or other appropriate [sic], that would occur while fishing according to the MSY control rule. The MSY stock size is the target stock size to which depleted stocks must be rebuilt.

The most important feature of this definition of BMSY is that it is a function of the management policy, the "MSY control rule" (such as a constant harvest rate policy). Under a MSY control rule, the stock will fluctuate above and below the target BMSY and would be expected to be below BMSY half of the time. However, it is recognized that the yield will be close to MSY over a significant range of stock sizes around MSY and that so long as the MSY control rule keeps the stock within that range, yield will be near MSY. One could argue that any stock size below BMSY is "overfished," that is, the stock size is less than the stock size that will produce MSY. However, in recognition that

> (1) the yield curve is always reasonably flat in the region of BMSY, and
>
> (2) natural fluctuations in recruitment make it impossible for most stocks to hold the population exactly at BMSY, most agencies define a stock

Figure 1. Two yield curves. The panel on the left relating average surplus production (sustainable yield) to stock biomass, the curve on the right surplus production to fishing mortality rate.



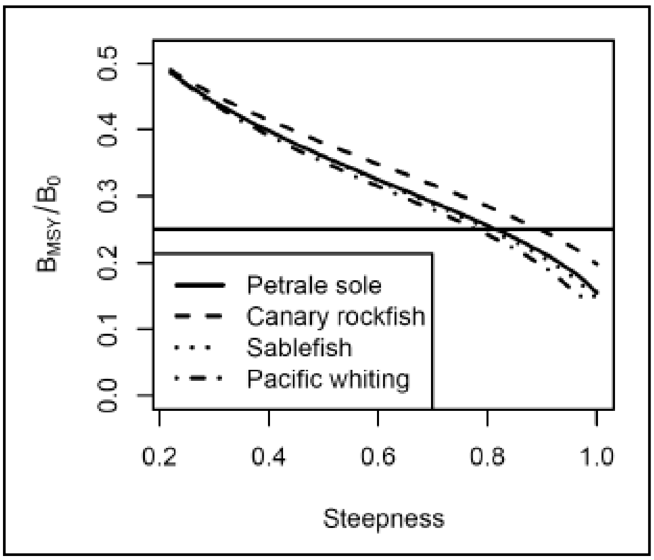
as overfished only if it is well below BMSY. The U.S. National Standard Guidelines specify half BMSY as a guideline for the level that constitutes overfished, although fishery management councils are free to choose their own definition. The National Standards have also replaced the term "overfished" with "depleted."

The Australians also define overfished as half BMSY (Department of Agriculture Fisheries and Forestry 2007; Rayns 2007). Their "harvest strategy standards" state they should have a "scientifically robust harvest strategy designed to achieve a sustainable target level and that does not result in overfishing or overfished stocks."

DEFINING BMSY

The population dynamics models that have become standard in fisheries management can easily be used to calculate BMSY as a function of the biological parameters of growth, survival, vulnerability to fishing gear, and recruitment. For stocks where the information is high and these parameters can be estimated, it is common to calculate BMSY as a function of the theoretical level the stock would achieve in the unfished state, sometimes called "virgin biomass" or more commonly B0, indicating the biomass under an exploitation rate of 0. It turns out that only one life history parameter is really important in determining the ratio of BMSY to B0, and that is the amount of compensation in the spawner-recruit curve (Hilborn 2010). Compensation is now frequently described as a parameter called steepness, the proportion of the unfished average recruitment that would be obtained at 0.2 B0 (Myers et al. 2002). Figure 2, from Punt et al. (2008) shows the relationship between steepness and the ratio between BMSY and B0 for four species of groundfish with diverse life histories (natural mortality rate, age at maturity, vulnerability curve) managed by the Pacific Fisheries Management Council (PFMC) in the United States.

Figure 2. The relationship between steepness and the ratio of BMSY to B0 for four different fish life histories. Reproduced with permission from Figure 3 of Punt et al. 2008.



Punt et al. (2008) have done all of their calculations based on a Beverton-Holt spawner recruit curve, which is the standard assumption in almost all organizations we are familiar with. The Ricker spawner recruit curve does behave differently, because at higher steepness values the recruitment initially rises as spawning stock declines, and steepness can be, in theory, greater than 1.0. Most agencies prefer not to use Ricker recruitment curves, perhaps because the assumptions that lead to its derivation are cannibalism or redd superimposition that are viewed as unlikely, or perhaps because the idea of recruitment increasing with declining stock size is counterintuitive. However, if one does use the Ricker curve, then the level of BMSY/B0 is in the range of 30–40% regardless of steepness (unpublished results of authors). Throughout the rest of this article we will use the Beverton-Holt assumption as is consistent with most agency practice.

Also shown in this figure is the horizontal line at 0.25 B0, which is the PFMC default definition of "overfished" for groundfish. It is immediately obvious that for most stocks, if steepness was greater than about 0.8, stocks that are at BMSY would be classified as overfished! U.S. fishery management councils are free to choose their own definitions for overfished, and the PFMC 25% B0 definition is clearly at odds with the National Standards guideline of half BMSY.

The most exhaustive surveys of recruitment compensation were performed in the meta-analysis of Myers and colleagues (e.g., Myers et al. 1999, 2002). Table 1 shows the distribution of estimates of steepness for the three taxa of marine fish for which greater than 10 stocks had sufficient data to allow estimation (Myers et al. 1999). These stocks all show quite high steepness, with mid-points between 0.7 and 0.8. Referring back to Figure 2, this would imply that BMSY for these stocks is, on average, in the range of 25-30% of B0 and, using the NOAA guidelines of half BMSY, stocks would be deemed to be overfished if they were at 12–15% B0.

Not all estimates of steepness have found such high values (see e.g., Dorn 2002), and the PFMC now uses a value of 0.6 as a default option for most groundfish stocks on the Pacific coast where many stocks appear to be quite unproductive compared to the North Atlantic stocks that dominated Myers' analysis. This default value of steepness (0.6) would imply that BMSY is about 30% of B0 and, in turn, that stocks would be classified as overfished at about 15% of B0.

While it is possible to define BMSY for stocks where all biological parameters are defined, for most stocks there is uncertainty in the spawner-recruit relationship and other parameters, particularly the natural mortality rate. In addition there may be major uncertainty associated with issues like model structure. Often, several alternative stock assessment models are proposed that may, for example, weight data sources differently. Therefore, any realistic estimate of BMSY would, of necessity, be probabilistic and reflect the underlying uncertainty. This poses great difficulty

Table 1. The estimated values of steepness for the three major marine fish taxa. From Myers et al. (1999).

Taxon	Number of data sets	Lower 20% bound	Midpoint	Upper 80% bound
Clupeidae	39	0.49	0.71	0.86
Gadidae	49	0.67	0.79	0.87
Pleuronectidae	14	0.71	0.80	0.87

for anyone seeking to answer simple questions like "Is this stock overfished?"

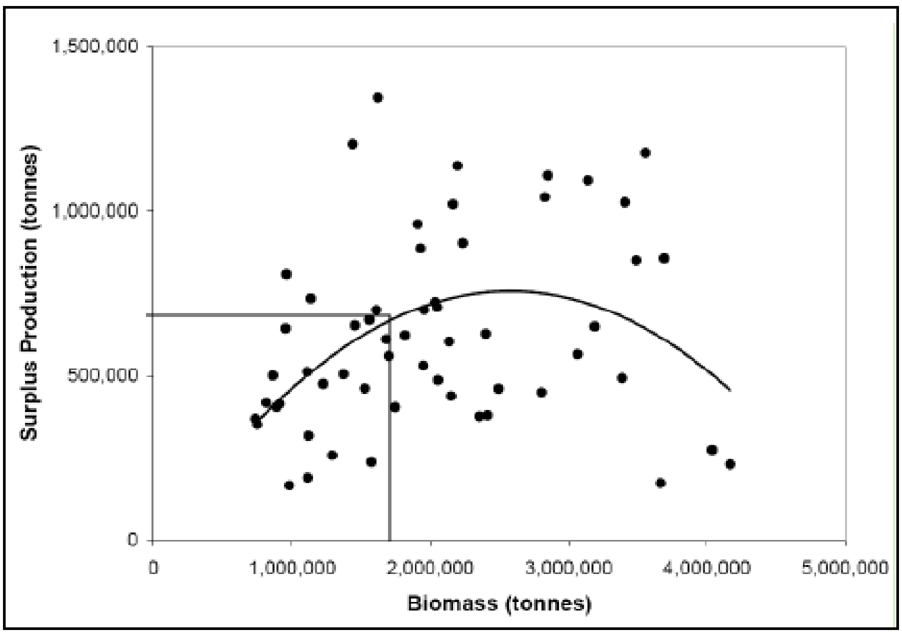
CONFRONTING UNCERTAINTY THROUGH MANAGEMENT STRATEGY EVALUATION

One approach to dealing with uncertainty is development of management strategies, that is, rules of how data will be collected, analyzed and used in setting harvest regulations (see e.g., Butterworth 2007). Part of the process is evaluating the performance of alternative strategies across a range of possible stock dynamics. A management strategy can often be found that performs well across the kinds of uncertainty in BMSY discussed previously. For instance, the management strategy adopted for rock lobsters (*Jasus edwardsii*) in New Zealand was shown to perform well under several alternative hypotheses even though these hypotheses had totally non-overlapping estimates of BMSY (Paul Starr, New Zealand Seafood Industry Council, pers. comm.). Management strategies are generally adopted based on their expected results in terms of yield, stock abundance, and catch rates. They are rarely based on estimates of BMSY or B0, in part because they are designed to be robust to uncertainty in these quantities, but some do make explicit reference to BMSY (Punt et al. 2008). Most management strategies that have been adopted can be said to be consistent with the intent of the legislative frameworks in that they are designed to avoid overfishing, but may not refer explicitly to BMSY.

One approach to developing management strategies is to use historical stock size as targets or breakpoints in the harvest control rules. Within the historical record, we usually know when stocks were abundant and productive, and for overfished stocks we know we would like to rebuild to those levels. Many stocks also have been historically fished to low abundance, and we know we would not want to go that low again. There is no need to tie our management strategies to unknowable quantities like B0 when we often have very well known reference points that can be broadly understood and applied. In the case of New Zealand rock lobster, different models produced widely different estimates of BMSY and no particular estimate of BMSY was considered to be credible. However, participants in the fishery and long-term managers were familiar with a period in the late 1970s/ early 1980s when yields and abundance as measured by CPUE were considered good. In this fishery they believe that CPUE is a good index of abundance. The target CPUE for the harvest control rule was set to the CPUE in that period. Similarly, when the Commission for the Conservation of Southern Bluefin Tuna was considering a target for stock rebuilding, it chose the abundance in 1980 because it had been a period of good abundance and economic performance. These reference points can be absolute biomass from assessments, or survey indices.

A closely related approach is simply to examine the historical relationship between stock size and surplus production, as shown in Figure 3 for the northeast Arctic cod (*Gadus morhua*) stock (Walters et al. 2008). Each dot is the estimated surplus production calculated from the catch and estimated biomass of the stock assessment. The solid line is a simple quadratic fit and the thin line is the stock size estimated in the last year of the assessment and the associated expected surplus production. The biomass where the quadratic curve reaches its highest point, roughly 2,700,000 tons, could be considered the target for fisheries management. While this approach can be viewed as a classic method for estimating BMSY and does depend on a stock assessment model, it is an empirical approach that makes no attempt to estimate B0 and sets targets based on historical estimates of surplus production.

Figure 3. The relationship between stock biomass and surplus production for the northeast Arctic cod stock from northern Norway. The thin vertical lines indicates the biomass and expected average surplus production in 2003, the last year the data were available.



DEFINING OVERFISHED

Returning to the theory of overfishing and the evolution of the legislative frameworks, it has always been recognized that MSY is not obtained from a single stock size, but over a range of stock sizes. The yield curves are usually quite flat over a range of stock sizes (Hilborn 2010) and management agencies have generally set biomass levels to define stocks as being overfished as a fraction of BMSY. In the U.S. National Standards and Australian terminology, the overfished threshold is called "Blim," and the default value in both places is half of BMSY. Once a stock falls below Blim, it is considered overfished. So long as the stock biomass is greater than Blim, the stock is considered to be within the bounds of normal management unless overfishing is occurring and the stock is under a rebuilding plan.

The U.S. legislation is designed to avoid managing stocks at biomasses so low that significant potential yield is being lost. Paragraph (6) of the Magnuson-Stevens Act states:

A national program for the conservation and management of the fishery resources of the United States is necessary to prevent overfishing, to rebuild overfished stocks.

Paragraph (34) states:

The terms "overfishing" and "overfished" mean a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis.

A major purpose of the act is to prevent overfishing, where overfishing is synonymous with reducing yield. Thus, lost yield is, presumably, the basis for the NOAA choice of half of BMSY as the default overfished threshold. The sustainable yield at half BMSY ranges from about 83–93% of MSY for steepness from 0.5 to 0.9 and it would certainly be reasonable to adopt a definition of being overfished as any stock size where the expected yield is (say) 80% or less than MSY.

If the purpose of definitions of "overfished," and associated thresholds, is to identify stocks that are at levels where potential yield is being lost, the "sin" that Larkin referred to earlier, then thresholds such as the 25% B0 adopted by the Pacific Fisheries Management Council for groundfish are inappropriate. With a steepness of 0.6, well below the median range of 0.7–0.8 identified by the work of Myers et al. (1999), stocks would typically be producing 98% of MSY—hardly a loss of yield that is measurable or significant. Even with a steepness of 0.3 (well below the 20th percentile of steepness estimates for any class of fish identified by Myers et al. 2002; Table 1), the stock would still be producing 75% of MSY.

Other agencies have also adopted default definitions of BMSY and of being overfished using standard "default" values. In fisheries managed by the Australian Commonwealth Government, 40% B0 is taken as the default BMSY value, modified to a target of 48% B0 by economic arguments, and 20% B0 is taken as a default level at which directed fishing should be closed (Department of Agriculture Fisheries and Forestry 2007). These default values can be replaced by stock-specific parameters where available, and when stocks fall below the lower limit, a stock specific rebuilding plan is usually put in place, with allowances for bycatch in other fisheries.

Australia and other agencies have often cited Myers et al. (1994) as the definitive paper supporting 20% B0 as a threshold for overfishing, but this is a serious misinterpretation of the results of that paper. Myers et al. (1994) showed that the recruitment does decline for most stocks at low stock sizes where data were available and the authors of that paper say that:

...it [their analysis] should help dispel the widely-held notion that observed recruitment is "usually independent of spawning biomass."

The paper does not in any way, however, suggest that 20% B0 is a useful threshold for defining overfishing. Indeed, Myers et al. (1994) caution specifically against using 20% B0:

Methods based on 20% B0 were included in this study because they have been widely applied (Beddington and Cooke 1983; Francis 1992); however, based on both empirical and theoretical considerations we do not recommend them for general use. These methods often placed the critical point well beyond the range of the observations (e.g., in 36% of cases for BHv). In addition, they suffer from two other related problems: inaccuracies in the estimates of virgin biomass, and the inappropriateness of applying the 20% level universally. Estimates of virgin biomass calculated by the method used here are inaccurate because they assume stationarity (e.g., no density-dependent processes) to calculate the F = O replacement line and generally rely on extrapolating the S-R data beyond the range of the observations. Similarly, a threshold of 20% B0 will not be universally applicable since different stocks have different degrees of compensation (i.e., density-dependence) in recruitment and other life-history processes. (Myers et al. 1994:204)

The later work of Myers and others, especially Myers et al. 1999 and Myers et al. 2002, as shown in Table 1, provides a much more solid framework for understanding the relationship between biomass and sustainable yield, and thus definitions of overfishing.

The problems in using B0 are severe. B0 is almost always estimated by taking estimated recruitments and extrapolating to a population size that would occur if these recruitments were allowed to mature in the absence of fishing. This usually done by multiplying average recruitment times spawning biomass per recruit in the absence of fishing. Such an approach completely ignores the possibility of density-dependent somatic growth and mortality, yet both phenomena are expected to occur for ecological reasons. Density-dependent growth has been documented as a frequent occurrence in exploited populations (Lorenzen and Enberg 2002). Density-dependent mortality is difficult to measure but has been documented at a range of life history stages (Myers 1995; Rose et al. 2001) and is expected from any trophic analysis of an ecosystem.

We can explore the impact of spawner-recruit compensation (steepness) further. Table 2 shows the relationship between steepness and several key parameters for a cod-like fish stock with a natural mortality rate of 0.2, von-Bertalanffy growth (k) of 0.2, maturing at age 5, and becoming vulnerable to fishing at age 4. These results are derived from the deterministic yield curve, but stochastic simulation shows similar results. This simple example shows, in particular, that BMSY for the range of most of the observed steepnesses of exploited marine fishes (i.e., steepness 0.6 or higher) is at 31% B0 or less, and for most stocks in Myers' analysis (with steepness in the range 0.7 to 0.9) is near or under 20% B0. At half BMSY, the yield is almost always quite high, and there is effectively no lost yield due to overfishing at a value of 25% B0 except for steepness values less than 0.5. Further, it shows, based on Myers et al. 1999 meta-analysis using 0.7 as an average steep-

Table 2. The relationship between steepness and several BMSY related parameters for a cod-like fish stock.

Steepness	BMSY	Yield at 1/2 BMSY	SBPRMSY	Yield at 25% B0
0.3	0.45	0.75	0.77	75%
0.4	0.38	0.73	0.61	87%
0.5	0.36	0.83	0.52	93%
0.6	0.31	0.85	0.42	98%
0.7	0.26	0.87	0.34	100%
0.8	0.22	0.88	0.26	100%
0.9	0.16	0.93	0.19	97%*

*BMSY is less than 25% B0 and this lost yield represents underfishing rather than overfishing ness, that 25% B0 would be a good default assumption for BMSY, and that, on average, little sustainable yield would be expected to be lost with stock sizes as low as 12% BMSY. The PMFC and Australian Government have adopted 40% B0 as a standard for BMSY. Others (e.g., New Zealand) appear to be following suit. This is unrealistic based on the biology of exploited fish species. We should note, however, that the flat yield curve means that the expected yield at stock sizes higher than BMSY is also close to MSY and there would be little loss of yield from harvest policies that consistently maintain the stock above BMSY.

We suggest two logical ways to define stocks that are overfished. The first would be to use a lost-yield threshold, with 80% being an obvious suggestion based on Table 2. This would mean that overfished would be less than half BMSY for stocks with steepness > 0.5, and higher than half BMSY for stocks with steepness below 0.5. An alternative definition would be based on the range of stock sizes that are predicted to occur from a FMSY harvest strategy. Again, one could choose the 80% probability distribution as the bounds, so that there would be only a 10% chance of a stock managed by FMSY being classified as "overfished."

ACCOUNTING FOR RISK AND DEPENSATION

The use of 20% B0 as a standard for defining stocks as being overfished developed during the 1980s and 1990s (Beddington and Cooke 1983; Francis 1992); the conventional wisdom being that "bad things" might happen when stocks go below this level. "Something bad" may be declines in recruitment or, even worse, depensatory recruitment or survival when populations get to low abundance. In New Zealand, the concern about going below 20% B0 has become institutionalized, so that the definition of BMSY requires that the stock not go below 20% B0 more than 10% of the time under a MSY harvest strategy (so-called CAY or MCY policies—see e.g., Sullivan et al. 2005). This has the effect of defining BMSY as a larger number than calculated from the yield curves as shown earlier.

The primary concern about being below 20% B0 is recruitment overfishing, and the analysis from Table 2 shows that only for the lowest steepness values is there significant lost yield at that level. In the sense of the legislative history and the wording of UNCLOS, 20% B0 is almost certainly a level that produces very close to the maximum sustainable yield for most fish stocks.

The second possible concern about lower stock sizes is depensation. Two papers have explored the evidence for depensatory mechanisms in recruitment across a wide range of fisheries. Myers et al. (1995) and Liermann and Hilborn (1997) both used the spawner-recruit database assembled by Myers and found little evidence for depensatory recruitment processes. There is good evidence that recruitment declines at low stock abundance, but not in a depensatory fashion that could lead to collapse. Walters and Kitchell (2001) have argued that community shifts could lead to depensatory dynamics only after stocks had been at low abundances for many years. Shelton and Healey (1999) argued that this could have happened with the northern cod in Eastern Canada. However, the northern cod stock was pushed to a very small fraction of B0, and there remains little evidence for depensatory dynamics as a frequent phenomenon in exploited fish populations.

REFERENCE POINTS FOR MANAGEMENT

Many jurisdictions have now defined formal harvest strategies built around three key biomass reference points: a target biomass about which the stock is meant to fluctuate, a "hard" limit where directed fishing should stop, and a "soft" limit (between the target and the hard limit) below which a formal rebuilding plan be put in place and generally where stocks are considered overfished or depleted. In the PFMC groundfish management plan, 40% of the theoretical unfished biomass (B0) is considered the target, 25% B0 is the soft limit and formal definition of being overfished, and 10% B0 is the hard limit. In Australia, the target defaults to 1.2 x BMSY (48% B0); the hard limit is half BMSY (20% B0). NOAA has adopted half BMSY as a standard guideline for levels that constitute being overfished.

All of the calculations and discussion of MSY-related reference points thus far have concerned the issue of yield and concern about lost yield from overfishing. This is a totally distinct issue from what reference points should be used in formulating management policies. There are many good reasons that management agencies and fishing entities would like to operate fish stocks at biomasses larger than BMSY. For instance, the economics of fishing are generally more profitable at larger stock biomasses (Grafton et al. 2007) and there are fewer ecological impacts (Worm et al. 2009). Thus it may be quite reasonable to set target biomass well above BMSY, and to have fishing mortality rates reduced when the stock drops below BMSY. There may have been significant ecosystem changes that mean the data from the past are not relevant to the current productivity of the stock. To some extent this is simply reverting back to the 1970s and replacing MSY as a fisheries objective with an "optimum yield" that considers economic and ecological impacts in addition to biomass harvested. However, it must be recognized that the idea of using BMSY as a lower limit is completely arbitrary, and is not related to yield and or overfishing. It is simply that BMSY is a concept people (think they) are familiar with.

Punt et al. (2008) have shown that the management performance of different strategies that use threshold breakpoints (as the PFMC and Australian Government do) are broadly insensitive to the actual thresholds. So long as catches are reduced as stock size declines, the management strategies provide good yield. In particular, the lower thresholds where directed fishing is stopped are reasonably unimportant since a well-managed stock would rarely get to those levels. However, where they do matter a great deal is with most of the world's real fisheries, where many are at lower abundance than we would choose to operate if we had our choice. If one accepts that a good target for fisheries management is at abundances higher than BMSY—for ecological and economic reasons—then many commercial fisheries are below this target level. Worm et al. (2009) estimated two-thirds of the stocks they examined had biomass currently lower than BMSY. The two key questions then become:

(1) What is the value of rebuilding to higher stock abundances given we are at lower abundance, and

(2) How quickly should this rebuilding take place?

We can answer the first question biologically by looking at the yield curve, but we could only answer the second question if we had an objective such as maximum discounted yield or profit. In practice, rebuilding times have often/usually been dictated arbitrarily, with no underlying justification being given.

CONCLUSIONS

In the United States, and increasingly elsewhere, stopping stocks from becoming overfished, and stopping overfishing, have become the holy grails of fisheries management, yet the scientific community has been imprecise and perhaps even dishonest in defining what "overfished" actually is. As shown above many of the definitions of being overfished (or of overfishing) now in place cannot be justified on biological or legal grounds. A sort of "international group think" has taken over in which different jurisdictions cite other jurisdictions use of 20% B0, 40% B0, and B0 itself as a basis for policies without evaluating the legitimacy of these specific reference points.

It can be argued that the increasing concern about ecological impacts of fishing and the economics of fishing has led to a new concept of overfishing, and definitions like the PFMC's 25% B0 represent not overfishing from lost yield, but economic or ecological overfishing. The "new" overfishing would represent a reincarnation of "optimum yield" from the 1970s. This is a perfectly viable approach, but must be recognized as totally arbitrary unless supported with an underlying quantitative basis.

In practice, almost all justification of thresholds for overfishing claims to be based on legislation and the traditional concern about yield lost from overfishing. We have no doubt the general public perceives overfished stocks as having been fished so hard that they are not producing near their sustainable yield. It seems ironic that many agencies choose high thresholds for defining stocks as overfished and then use these thresholds to evaluate their own performance, making themselves look bad as a result.

We recommend that management agencies distinguish between stocks that are losing yield due to overfishing, and stocks that are at lower biomass than would be desired for ecological or economic reasons. The scientific data suggest that 25-30% B0 would be the most justifiable level for a default BMSY, and that 10% B0 would probably represent a typical level at which more than 10% of potential yield was being lost. In cases where the spawner-recruit steepness can be estimated, the guidelines could be replaced by the results from the yield curve.

What the standard approaches to biomass reference points in the United States and Australia fail to make clear is that they are tied to an almost unknowable quantity, the unfished biomass B0. Targets and limits for fisheries management based on historical stock sizes and stock productivity have the advantage that they are based on experience, are easily understood, and are not subject to the vagaries of model assumptions. While such targets and limits are not explicitly based on the empirical estimates of BMSY, they are completely consistent with the intent of most national and international fisheries legislation—to avoid loss of yield by overfishing.

The tension between B0-based targets and historically-based targets centers on the question of who should determine fisheries management targets. In the United States, especially with the recent reauthorization of the Magnuson-Stevens Act, there is a desire to have fisheries management be science-based, and having harvest strategies determined by model outputs such as a percent of B0 clearly puts the decision making in the hands of the scientists. We feel this is misguided for two reasons. First, scientists have no special knowledge regarding appropriate fisheries policy. Scientists should simply evaluate the consequences of alternatives being considered. Secondly, the stakeholders in a fishery and the political process should determine fisheries management choices; while the stakeholders understand historical levels of abundance, they seldom understand model outputs such as %B0. To the extent that there is no scientific way to determine what a "good" period of fisheries performance was, we view that as a positive step in putting decision-making back in the hands of the stakeholders.

It is likely that socially "optimal" harvest strategies may seek to hold stocks, on average, at high stock sizes for economic, ecological, or social reasons (Hilborn 2007). However, such choices need to be evaluated on a case-by-case basis, and there is a need to be very clear what it is that causes larger stock sizes to be socially desirable. At present, it seems that those advocating larger stock sizes for ecological reasons are using the legislative requirements to avoid lost yield from overfishing, and distorting the science in the process, as an excuse to achieve objectives not considered when the legislation was drafted.

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FEATURE:
INTRODUCED SPECIES

Aquatic Invasive Species Transport via Trailered Boats: What Is Being Moved, Who Is Moving It, and What Can Be Done

ABSTRACT: Trailered boats have been implicated in the spread of aquatic invasive species. There has been, however, little empirical research on the type and quantity of aquatic invasive species being transported, nor on the efficacy of management interventions (e.g., inspection crews, boat washing). In a study of small-craft boats and trailers, we collected numerous aquatic and terrestrial organisms, including some species that are morphologically similar to known aquatic invasive species. Additionally, a mail survey of registered boaters (*n* = 944, 11% response rate) and an in-person survey of boaters in the field (*n* = 459, 90% response rate) both indicated that more than two-thirds of boaters do not always take steps to clean their boats. Furthermore, we used a controlled experiment to learn that visual inspection and hand removal can reduce the amount of macrophytes on boats by 88% ± 5% (mean ± SE), with high-pressure washing equally as effective (83% ± 4%) and low-pressure washing less so (62% ± 3% removal rate). For removing small-bodied organisms, high-pressure washing was most effective with a 91% ± 2% removal rate; low-pressure washing and hand removal were less effective (74% ± 6% and 65% ± 4% removal rates, respectively). This research supports the widespread belief that trailered boats are an important vector in the spread of aquatic invasive species, and suggests that many boaters have not yet adopted consistent and effective boat cleaning habits. Therefore, additional management efforts may be appropriate.

Especies acuáticas invasivas transportadas vía botes con remolque: qué se está moviendo, quién lo mueve y qué puede hacerse

RESUMEN: Los botes con remolque han sido implicados en la dispersión de especies acuáticas invasivas. Sin embargo, se ha llevado a cabo poca investigación empírica acerca del tipo y cantidad de especies acuáticas invasivas que están siendo transportadas así como de la eficacia del manejo a este respecto (p.e. tripulación para inspección y lavado de botes). En un estudio realizado acerca de pequeñas embarcaciones y remolques, se colectaron numerosos organismos acuáticos y terrestres, incluyendo algunas especies que son morfológicamente similares a especies acuáticas invasivas previamente conocidas. Adicionalmente se hizo un sondeo por correo a los dueños registrados de las embarcaciones (n = 944, 11% de tasa de respuesta) y un sondeo en persona en campo (n = 459, 90% tasa de respuesta). Ambos sondeos indicaron que más de dos tercios de dichos dueños no siempre limpian sus botes. Más aún, se hizo un experimento en condiciones controladas para determinar que la inspección visual y la remoción manual pueden reducir la cantidad de macrofitas en los botes hasta en un 88% ± 5% (media ± EE), siendo igualmente efectivo el lavado a alta presión (83% ± 4%) mientras que el lavado a baja presión no lo fue tanto (62% ± 3% tasa de remoción). En cuanto a la remoción de animales pequeños, el lavado a alta presión fue el más efectivo con un 91% ± 2% de tasa de remoción; el lavado con baja presión y la remoción manual fueron menos efectivos (74% ± 6% y 65% ± 4% de tasa de remoción, respectivamente). Este estudio apoya la creencia común que los botes con remolque son un vector importante en la dispersión de especies acuáticas invasivas; se sugiere, además, que muchos dueños de botes aun no han adoptado hábitos de limpieza consistentes y efectivos. Por lo resultan adecuados esfuerzos de manejo adicionales.

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Invasive aquatic plants, such as Eurasian watermilfoil, can be transported among waterways when they become entangled on recreational boats, motors, and trailers.

INTRODUCTION

Much of the ongoing spread of aquatic invasive species (AIS) to inland waters throughout North America can be attributed to the overland movement of small-craft boats (Bossenbroek et al. 2001; Johnson et al. 2001; Leung et al. 2006). Small-craft boats are vessels less than 40 feet (12.2 m) in length, including powerboats, small commercial and recreational fishing boats, sailboats, personal watercraft, canoes and kayaks, and pontoon boats, that can be towed overland on trailers. Translocation of organisms by boaters can be intentional (e.g., as bait; Keller et al. 2007), but is often unintentional (Johnson et al. 2001; Puth and Post 2005), with organisms inadvertently carried in bilge water, live wells, and bait buckets. Organisms can also be entrained on boat exteriors, e.g., entangled on propellers and trailers, attached to other entangled organisms (Johnson et al. 2001). Thus, every time a boat is transported overland after use in an invaded waterway, there is the possibility that it will transfer AIS to uninvaded waterways.

Overland transport of small-craft boats is thought to be responsible for the spread of spiny waterflea (*Bythotrephes longimanus*; MacIsaac et al. 2004; Muirhead and MacIsaac 2005), Eurasian watermilfoil (*Myriophyllum spicatum*; Buchan and Padilla 2000), and zebra and quagga mussels (*Dreissena* spp.; Schneider et al. 1998; Leung et al. 2004; Stokstad 2007). These organisms are known to have considerable negative effects on the aquatic ecosystems they invade, with impacts including damages to fisheries (Vanderploeg et al. 2002; Mills et al. 2003; Marsden and Robillard 2004), interference with raw water usage (O'Neill 1996; Leung et al. 2002), decreased property values (Halstead et al. 2003), extirpation of native species (Nalepa et al. 1996; Strayer 1999), and threats to human health (Vanderploeg et al. 2001; Yule et al. 2006; Hogan et al. 2007). The recent invasion of the Great Lakes and inland lakes by Viral Hemorrhagic Septicemia (VHS, a fish virus; Lovell and Drake 2009) further emphasizes the potentially serious consequences of moving biological materials among waterways (Elsayed et al. 2006).

The Great Lakes region provides an opportunity to study how to better manage the risks of AIS spread by small-craft boaters. There are numerous aquatic resources in the region, including the Great Lakes themselves as well as abundant inland waterways. Moreover, recreational boating is an important driver of the regional economy (RMRC 2006). In the eight U.S. states bordering the Great Lakes, there are 4.2 million small-craft boats, nearly a third of all those currently in use in the United States (Thorp and Stone 2000). Likewise, in the Canadian provinces of Ontario and Quebec, there are over 2 million recreational boats (Thorp and Stone 2000).

The quality of the region's aquatic resources is threatened by AIS. For example, over 300 lakes in the region and multiple rivers have been invaded by zebra mussels, fouling water intakes of industrial facilities and reducing native biodiversity (Johnson et al. 2006). Eurasian watermilfoil, an invasive macrophyte that impairs navigation and recreation and displaces native macrophytes, is present in nearly 1,000 lakes in Michigan, Wisconsin, Illinois, and Indiana. The impacts of these and other species, combined with the importance of the resources they harm, have resulted in the region becoming a test bed for science and policy pertaining to the ecology and impacts of AIS. Thus, the stakeholders in the region tend to be generally aware of AIS issues and are concerned about reducing AIS impacts. In some cases, however, stakeholders lack empirical data about the spread of AIS by small-craft boaters and about the effectiveness of various techniques proposed to restrict spread. This lack of knowledge can limit the confidence of managers and the public that management interventions to limit spread of AIS are worthwhile.

Efforts to stem the spread of AIS via trailered boats in the Great Lakes region, as in most other regions, have focused on pre-launch boat inspections at uninvaded waterways and on campaigns to educate the public on actions that individuals can take to reduce the likelihood of transporting AIS. In contrast to pre-launch inspections sponsored by lake associations and government agencies, education campaigns emphasize boat inspection and cleaning when leaving a waterway. For example, regional campaigns such as the Clean Boats/Clean Waters programs of Wisconsin and Michigan (www.uwsp.edu/cnr/uwexlakes/cbcw/) and national programs such as Protect Your Waters (http://protectyourwaters.net) recommend the following actions for boaters to reduce their likelihood of transporting AIS: "(1) inspect and remove aquatic plants, animals, and mud from boat, trailer, and equipment before leaving the landing, (2) drain all water from boat, motor, live wells, bilge, bait buckets and other containers before leaving the landing, (3) ice your catch; don't leave landing with any live fish, bait, or fish eggs, (4) dispose of unused bait in trash, not in the water or on land, and (5) rinse boat and equipment with hot or high pressure water or dry boat for at least five days" (www.uwsp.edu/cnr/uwexlakes/cbcw/Pubs/AISprevention_steps.pdf). Regarding this fifth recommendation, some natural resource managers and private citizens advocate boat-washing stations on the public landings of waterways, contending that high-pressure washing is necessary to remove biological materials effectively.

Surprisingly, no rigorous scientific research is available on the efficacy of the main techniques advocated for removing organisms from trailered boats. Furthermore, few empirical efforts have quantified the types and numbers of organisms in transport. Moreover, data on boater compliance with the above-listed recommendations for preventing the spread of AIS are also lacking, and it is unknown if different sub-groups of boaters (e.g., recreational boaters, professional fishing guides) differ in their boat hygiene behaviors and, therefore, in their likelihood to transport organisms. A better understanding of these aspects of the trailered boat pathway is critical to improve policy and management intended to reduce the threat of additional invasions.

This report draws on data from an observational study, two surveys, and an experiment to reduce uncertainty in our understanding of the risks of AIS transport posed by the trailered boat pathway, and to examine efficacy of various cleaning techniques to remove organisms from the pathway. We estimate the number of organisms being transported by presenting data on the type and quantities of organisms collected from the external surfaces of boats and trailers. We document the steps boaters take to prevent AIS transport and how these behaviors may differ across sub-groups of boaters by surveying registered boaters by mail and in person. Finally, we experimentally test the efficacy of the three most common boat-cleaning methods (i.e., visual inspection and hand removal, low-pressure washing, and high-pressure washing) in removing organisms (i.e., macrophytes, zooplankton, and plant seeds) from the exterior surfaces of boats and trailers.

METHODS

Observational Study

We washed 85 boats arriving at (n = 36) and departing from (n = 49) two popular boat landings in the Northern Highlands Lake District of northern Wisconsin and the Upper Peninsula of Michigan (Big St. Germain Lake, Vilas County, Wisconsin [Latitude: 45.9344, Longitude: -89.5163] and Lake Gogebic, Gogebic County, Michigan [Latitude: 46.4999, Longitude: -89.5835]), between 26 August and 5 September 2006 to gather data on the types and quantities of aquatic organisms inadvertently transported by recreational boaters. We selected these landings because of their popularity and because the design of the boat launch allowed for convenient set up of our boat washing equipment. Invasive spiny waterfleas are present in Lake Gogebic, but no AIS likely to be inadvertently transported by recreational boaters are known to exist in Big St. Germain Lake. The size (e.g., number of parking spaces) and development (e.g., ramp construction material) of these landings are representative of typical inland lake public boat access sites in the Great Lakes region.

All arriving and departing boats were washed using a portable high-pressure wash and reclaim system, which was a modified version of a portable noxious weed removal system (WB500, Spika Manufacturing, Mocassin, Montana). This system, originally developed by the U.S. Forest Service to clean weed seeds and plant pathogens off vehicles and equipment used to fight wildfires (Trent et al. 2002), supplied the high-pressure wash (1800 psi) and the water filtration capabilities we desired. The wash water was captured on a waterproof mat and then pumped through a filtration and reclamation system, using a food-grade polyethylene filter (nominal pore size: 100 μm) that trapped materials removed from washed boats.

Although we washed a total of 85 boats, for logistical reasons, each filter collected the materials washed from 4 to 7 boats. The main reason for this pooling of samples was that boats tended to arrive at our washing station clustered together in time. Changing the filter in our washing unit took approximately 10 minutes. We estimate that at least one-half of the boats we washed would have bypassed our washing station because of their unwillingness to wait for filter changing. Because one of the main objectives of this aspect of our study was to obtain organisms from as many boats as possible, we chose to pool samples from multiple boats onto each filter. Thus, for the statistical analysis of this component of our research, the filter is the replicated unit of study. As filters were the replicated unit for this study, this gave us a sample size of 6 (filters) for arriving boats and 11 (filters) for departing boats. We used separate filters for departing versus arriving boats so that organisms originating from a lake could be distinguished from those arriving from elsewhere.

In the laboratory, we removed and weighed all material collected in the filters. We then subsampled the material from each sample (i.e., filter) by spreading it evenly over a flat-bottomed sorting tray divided into 12 equally-sized sectors. We used a random numbers table to select four sectors from which to collect material for detailed sorting and identification and enumeration of organisms and other biological materials. When drawing off material from a subsampled sector, we used an enclosed sectioning device with a foam bottom to form a watertight seal with the bottom of the tray to separate the sector from those adjacent to it and to prevent the inclusion in the subsample of any materials not in the chosen sector. We used information on the total wet mass of material collected in a filter (i.e., all collected material was weighed—not only that subsampled), the number of boats washed onto that filter, and the mean number of aquatic organisms in the four subsamples from each sample to calculate estimates of the quantity of biological materials moved over land on the exterior of recreational boats. Before the washing described above, each boat and trailer were inspected visually for vegetation fragments, all of which were removed, identified, and weighed. The visual inspection protocol followed the checkpoint guidelines given by the Wisconsin Clean Boats/Clean Waters program (www.uwsp.edu/cnr/uwexlakes/cbcw/handbook_forms/Check%20pts.pdf).

Mail Survey

We administered a mail survey in August 2005 to obtain data from a broad sample of small-craft boaters about their boat cleaning habits, particularly when moving their boat from one waterway to another. We mailed a total of 10,000 surveys to a random sample of registered boaters in Wisconsin and Michigan (i.e., 5,000 to each state), with the number of surveys sent to each county proportional to the number of registered boaters in each. We used the boater registration databases for the two states to select survey recipients.

For analysis, we combined the responses from both states. In the survey, we posed a number of questions about boaters' movement habits and other boating-related activities. Our main interests were how frequently boaters noticed and removed aquatic weeds attached to their boat and trailer, how regularly they cleaned their boat, what methods they used for boat cleaning, and how frequently they launched their boat in different lakes (Table 1).

In-person Northwoods Survey

We interviewed small-craft boaters in person to gather additional data on travel patterns and boat cleaning practices of boaters in the same region where we conducted our observational boat washing study. These interviews, conducted between 28 May and 15 August 2007, occurred at sites (e.g., lake association meetings, bait shops, campgrounds, and boat ramps) in several counties in and near the Northern Highlands Lake District of northern Wisconsin and the Upper Peninsula of Michigan, including Vilas and Oneida counties in Wisconsin and Iron, Gogebic, and Marquette counties in Michigan. We asked the same questions as those asked in the mail survey for these interviews (Table 1).

For the in-person survey, we interviewed two categories of boaters: general recreationalists (n = 424) and professional fishing guides (n = 35) to learn if these two categories of boaters had different movement patterns and boat hygiene practices that might affect their risk of spreading AIS.

Experiment

We performed two experiments to test the effects of cleaning method and duration on the removal of aquatic macrophytes (first experiment) and small-bodied animals and plant seeds (second experiment) from the exterior of recreational boats and trailers. In the macrophyte removal experiment, we used the invasive aquatic plant Eurasian watermilfoil as the test organism. In the

Table 1. Questions and responses from mail and in-person surveys are shown. Sample sizes are for the number of transient boaters (i.e., boaters that launch in more than one waterway during the season) that responded to the surveys.

Questions	Responses			
Before going from one lake or river to another, how often do you:	**Always**	**Sometimes**	**Never**	**Not applicable**
Clean your boat by rinsing, pressure washing, or drying?				
Mail (n = 396)	27%	34%	34%	5%
In-person: Guides (n = 35)	11%	75%	10%	4%
Recreational boaters (n = 135)	24%	42%	33%	13%
Notice weeds attached to your boat or trailer?				
Mail	9%	43%	40%	8%
In-person: Guides	11%	86%	0%	3%
Recreational boaters	42%	45%	9%	4%
Remove any aquatic weeds attached to your boat or trailer?				
Mail	57%	14%	13%	16%
In-person: Guides	96%	0%	0%	4%
Recreational boaters	87%	10%	1%	2%
If you trailer your boat among waterways, in how many different waterways have you launched your boat in the past two weeks? (mean ± SE)				
Mail	2.66 ± 0.14			
In-person: Guides	5.41 ± 0.80			
Recreational boaters	2.72 ± 0.42			

small-bodied organism experiment, our test organisms were the spiny waterflea, an invasive cladoceran, and the seeds of three species of wetland plants (*Alisma subcordatum*, *Verbena hastata*, and *Carex frankii*). The six cleaning treatments were identical in both experiments, and resulted from the factorial crossing of three levels of cleaning method with two levels of cleaning duration (90 seconds and 180 seconds). The three levels of cleaning method were: 40 pounds per square inch (psi) wash water pressure ("low pressure" hereafter), 1,800 psi wash water pressure ("high pressure" hereafter), and visual inspection of the boat and trailer accompanied by hand removal of organisms. We repeated both cleaning experiments seven times for each of the six treatments.

During each experiment, one person—the same individual for all replicates—placed a known quantity of biological materials (52–153 g of milfoil for the macrophyte experiment; 100 each of seeds of 3 wetland plant species and *Bythotrephes*) on a boat and its trailer, recording the placement locations of all materials. Milfoil was placed on and around the propeller, on the trailer bunks, and on other protruding parts of the boat and trailer where it could plausibly become attached. Small-bodied organisms were embedded in a water-based gel (L. A. Looks Mega-Hold hair styling gel, Henkel Consumer Goods, Inc., Irvine, CA), mimicking mud or foam that might stick to a boat or trailer, and the gel was adhered to the boat or trailer. The locations where biological materials were placed were selected randomly for each replicate. The same boat, a general-purpose 16-foot aluminum V-hull motorboat (1993 Fisher 1675 Plus, Springfield, Missouri), and single-axle steel trailer were used in all replicates.

A different person then cleaned the boat using the specified cleaning method (i.e., low-pressure wash, high-pressure wash, or visual inspection) and time treatment (i.e., 90 s or 180 s). We captured and filtered all water used in each washing replicate using the same portable wash and reclaim system used in the observational study described above. Finally, the person who had initially placed the materials on the boat and trailer recovered any items still attached.

To calculate percent removal for the macrophyte experiment, we divided the initial minus the final mass of *M. spicatum* on the boat by its initial mass. To measure removal rates for seeds and *Bythotrephes*, we enumerated the seeds and zooplankton captured in the filtration system for each replicate and divided this by the number of small-bodied organisms originally on the boat (i.e., 300). To determine statistical significance of differences in percent removal among treatments, we used a two-way ANOVA on the data from each experiment (i.e., macrophyte and small-bodied organisms), followed by a post-hoc Tukey HSD test for multiple comparisons.

RESULTS

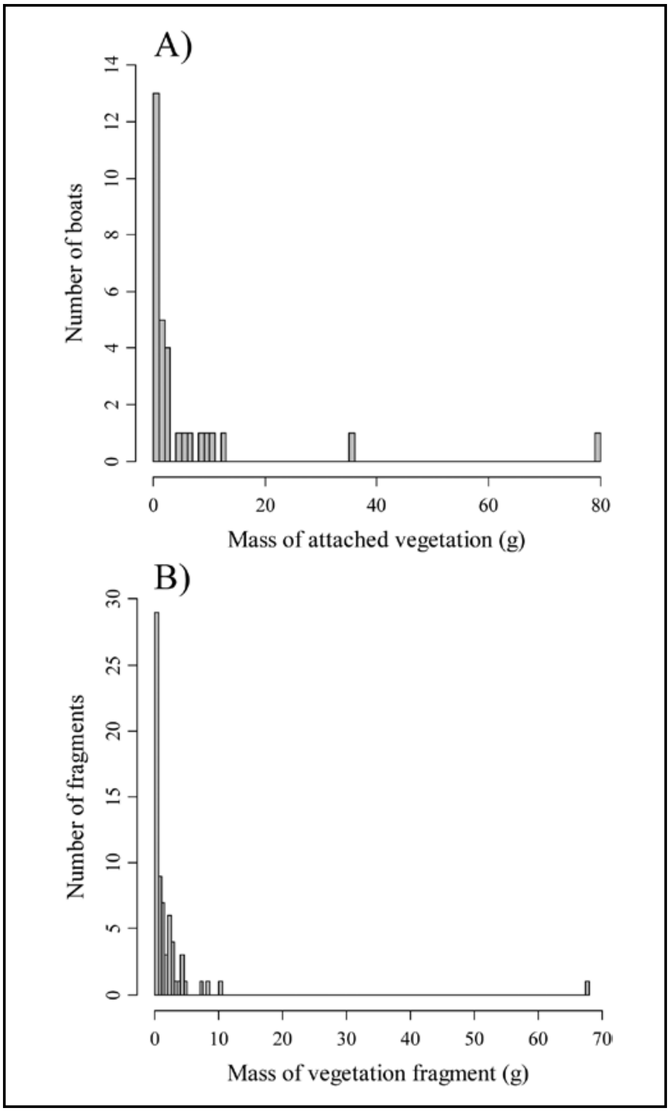
Observational Study

Of the 85 boats we inspected and washed during the observational study, 38 (45%) carried one or more plant fragments, but 30 of these had little material attached (i.e., < 5 g, Figure 1A). Boats and trailers leaving the lakes were three times more likely to be carrying vegetation than those arriving: 7 of 36 boats (19%) arriving at a lake had vegetation attached, whereas, 31 out of 49 boats (63%) leaving a lake had vegetation attached (Figure 2). The average biomass of macrophytes attached to a single boat and trailer was 6.4 ± 2.9 g (mean ± SE), with no statistically significant difference between boats leaving a lake and those arriving (Welch two-sample t-test: $t = -0.17$, df = 20.96, $P = 0.87$).

Of the 13 species of macrophytes collected from boats, none were invasive species (Table 2). We collected seven fragments of *Myriophyllum heterophyllum*, a native milfoil species that is morphologically similar to the invasive *M. spicatum*, a widespread nuisance species in North America. Most of the individual vegetation fragments we collected were very small, but some were quite large (Figure 1B).

We also collected 51 taxa of small-bodied organisms from the filter samples (Table 3), including 28 aquatic animals, among them amphipods, gastropods, and cladocerans. In our samples we found no AIS and no species known to be nonindigenous to the lakes where we worked. Among the aquatic organisms, 8 of the 18 orders we collected were crustaceans, including

Figure 1. Aquatic vegetation found attached to boats and trailers during field survey. Panel A is a histogram of the total mass of fragments on individual boats (bin width = 1 g). Panel B shows a histogram of the mass of individual vegetation fragments (bin width = 0.5 g).



zooplankton species (Table 3). Numerically, however, crustaceans, particularly zooplankton, were rarely encountered, with the exception of amphipods, which were abundant (Table 3). Aquatic insect larvae had lower taxonomic richness than crustaceans in our samples (4 of 18 orders encountered), but were numerically more common than the crustaceans. Midge larvae (Family: Chironomidae) were by far the most common aquatic organisms in our samples (Table 3). All three of the orders of mollusks we found in our samples were also relatively common numerically (Table 3). Most of the terrestrial organisms collected were either flying insects or tree seeds, primarily birch and elm (Table 3, Figure 2).

The average number of aquatic organisms transported on the boats and trailers we washed was 37.2. We cannot calculate the variability around this mean (e.g., standard error of the mean) because of the lost replicate identity that resulted from our pooling of multiple boats on to each filter and because of the uneven pooling of these samples (i.e., not every filter had the same number of boats washed on to it).

Mail Survey

A total of 515 boaters from Michigan and 429 from Wisconsin returned usable surveys. Some mailing addresses in the boater registration databases were outdated, resulting in 1,382 surveys returned as undeliverable. Thus, the response rate for the mail survey was 11% (i.e., 944/8,618). We did not conduct a non-response evaluation to determine the cause of this low response rate. More than half (58%) of the registered boaters responding to our survey reported that they kept their boat in the same waterway and therefore did not pose any risk of transporting AIS overland. The other 42% of respondents were transient boaters who launched their boat in multiple waterways during the boating season. For these boaters, the average number of different waterways in which they launched their boat in a two-week period was 2.66 ± 0.14 (mean ± SE). Of transient boaters, 27% said they always washed and/or dried their boat before launching it in a different waterway, 34% did this sometimes, and 34% never cleaned their boat (Table 1). For reasons unknown to us, the remaining 5% said that boat cleaning was not applicable to them.

The majority (57%) of transient boaters reported always removing aquatic weeds when noticed from their boats and trailers, but 14% said they did so only sometimes and 13% said they never removed aquatic weeds when they saw them (Table 1). The remaining 16% indicated that weed removal was not applicable to them, presumably because they never saw aquatic weeds attached to their boat or trailer. Thus, 68% of transient boaters did not always wash or dry their boat when moving it overland among waterways and 27% did not always remove aquatic weeds they saw attached to their boat and trailer.

In-person Northwoods Survey

Of the 508 individuals we approached for interviews, only 49 (46 recreationalists and 3 guides) declined to participate, giving a 90.4% response rate. Of the recreational boaters interviewed in person, most (68%) reported keeping their boat on a single lake for the entire season (e.g., spend summer camping by the only lake on which they launch their boats), and thus posed a low risk of spreading AIS. In our survey, a total of 135 recreational boaters (32%) reported using their boats at multiple lakes during the summer of 2007. When asked about AIS hygiene practices, 87% percent of recreational boaters reported always removing aquatic plants that they noticed attached to their boat or trailer, but 33% never pressure washed their boat or trailer (Table 1). In contrast to recreational boaters, professional fishing guides (n = 35 surveys) reported visiting nearly two times as many unique lakes in a two-week period (5.41 ± 0.80 vs. 2.72 ± 0.42 lakes, mean ± SE; Table 1). Furthermore, fishing guides were less likely than others to always clean their boats with washing and/or drying when moving between waterways (11% vs. 24%; Table 1). Fishing guides were also less likely to always notice aquatic weeds attached to their boats or trailers than recreational boaters (11% vs. 42%), but guides were more likely than others to always remove the weeds that they saw (96% vs. 87%; Table 1).

Experiment

High-pressure washing, and visual inspection combined with hand removal, removed a significantly greater percentage of

Figure 2. Average number and type of small-bodied organisms washed from recreational boats and trailers arriving at or departing from lakes in northern Wisconsin and the Upper Peninsula of Michigan. See Table 3 for further detail on taxa included in each taxonomic category.

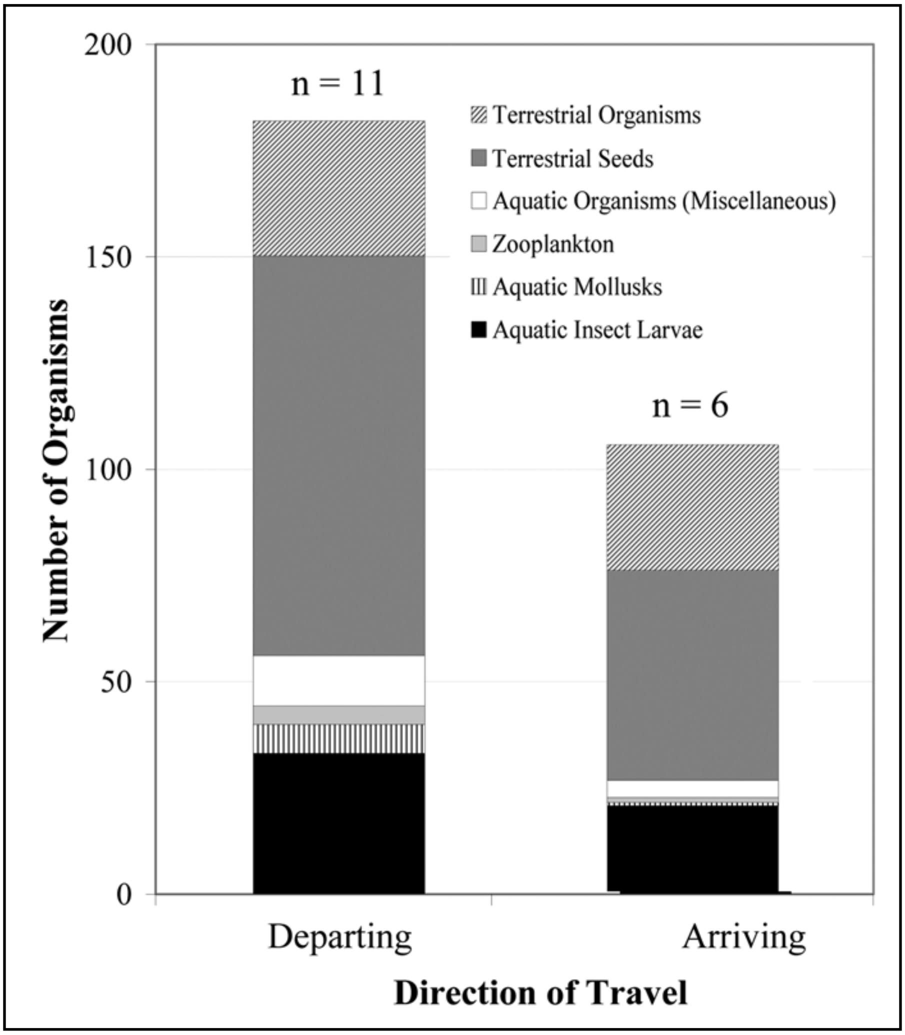


Table 2. Aquatic plant species and the respective number of fragments of each found on boats and trailers during observational field survey (sorted by frequency of occurrence).

Plant Species	# Fragments
Vallisneria americana	18
Potamogeton gramineus	9
Ceratophyllum demersum	8
Myriophyllum heterophyllum	7
Potamogeton pusillus	5
Potamogeton zosteriformis	5
Elodea canadensis	4
Najas sp.	4
Potamogeton richardsonii	2
Potamogeton robinsii	2
Zosterella dubia	2
Chara sp.	1
Potamogeton amplifolius	1

macrophyte vegetation than low-pressure washing ($F_{2, 36}$ = 21.1, P < 0.001; > 80% vs. ~63%; Figure 3A). High-pressure washing removed a significantly higher percentage of small-bodied organisms (i.e., wetland plant seeds and *Bythotrephes longimanus*) than did low-pressure washing or visual inspection plus hand removal ($F_{2, 36}$ = 15.4, P < 0.001; 90% vs. ~75%; Figure 3B). The duration of cleaning effort (90 vs. 180 s) did not significantly affect the percent removal of biological materials in either experiment (macrophytes: $F_{1, 36}$ = 0.81, P = 0.37; small-bodied organisms: $F_{1, 36}$ = 1.68, P = 0.20; Figure 3). There was also no significant interaction between cleaning method and duration of effort in either experiment (macrophytes: $F_{2, 36}$ = 0.30, P = 0.74; small-bodied organisms: $F_{2, 36}$ = 0.26, P = 0.77; Figure 3).

DISCUSSION

Widespread recognition that overland movements of boats are often responsible for spreading invasive plants (Buchan and Padilla 2000; Puth and Post 2005) and animals (Johnson et al. 2001; Muirhead and MacIsaac 2005; Keller and Lodge 2007) has prompted increased management concern. To date, however, management actions have largely focused on mitigating the impacts of these AIS through control and eradication efforts once they are already established in a body of water and inflicting harm (Simberloff et al. 2005; Lovell et al. 2006). Prevention efforts have been rarer, and most have concentrated on attempting to educate boaters about how individuals can reduce their likelihood of being a vector (www.uwsp.edu/cnr/uwexlakes/CBCW/). There are, however, no published studies that rigorously quantify the effectiveness of such education efforts in slowing the spread of AIS. Management actions specifically aimed at removing AIS from transportation pathways, such as recreational boats and trailers, may be a complementary and efficient way to reduce their spread (Lodge et al. 2006; Drury and Rothlisberger 2008).

Effectively managing the risk of AIS spread by small-craft boaters requires increased knowledge about what organisms are being transported, who is transporting organisms (i.e., how various sub-groups of boaters differ relative to their risk of transporting organisms), how often organisms are being transported, and how effectively various boat cleaning alternatives remove potentially harmful organisms from the pathway. Recent research efforts with implications for such decision-making have focused on predicting AIS spread based on network models of boater traffic among lakes (Leung et al. 2004, 2006; Drury and Rothlisberger 2008). For example, Drury and Rothlisberger (2008) demonstrated that for a wide range of hypothetical cleaning efficiencies (i.e., percentage of organisms removed through cleaning of boats and trailers) placing a given number of inspection and cleaning stations at invaded lakes slows landscape-level spread of AIS more effectively than placing the same number of stations at uninvaded lakes. Implicit in this and similar modeling efforts, however, are assumptions about the types and quantities of organisms being transported and about the ability of cleaning efforts to remove them from boats and trailers. This study provides some of the empirical data that was previously lacking, including the types of organisms boaters in the Upper Midwestern United States transport, the quantity of organ-

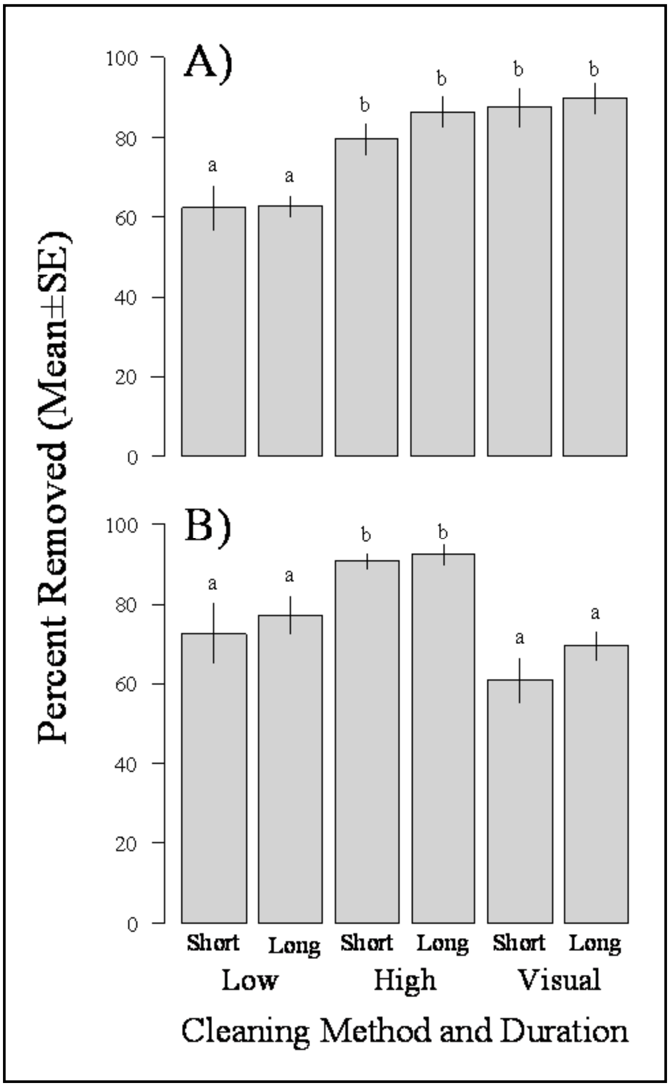
Table 3. Aquatic and terrestrial taxa collected in filters during the field survey. Taxa are identified variously to order, family, or genus.

Category	Order	Suborder	Family	Genus	Instar	Common Name	Total number collected from 85 boats washed (estimated from sub-samples)
Aquatic (Miscellaneous)	Amphipoda				Adult	Amphipod	209
	Isopoda				Adult	Isopod	3
	Oligochaete				Adult	Freshwater segmented worm	3
	Ostracoda				Adult	Ostracod	3
	Prostigmata				Adult	Water mite	206
Aquatic insect larvae	Diptera		Tipulidae		Larval	Cranefly	56
	Diptera		Chironomidae		Larval	Midge	740
	Diptera		Cuculidae		Larval	Mosquito	1
	Ephemeroptera		Baetidae		Larval	Baetid mayfly	18
	Ephemeroptera				Larval	Other mayfly	65
	Odonata	Zygoptera			Larval	Damselfly	18
	Odonata	Anisoptera			Larval	Dragonfly	89
	Trichoptera		Hydropsychidae		Larval	Caseless caddisfly	24
	Trichoptera		Leptoceridae		Larval	Leptocerid caddisfly	18
	Trichoptera				Larval	Other caddisfly	50
Aquatic mollusks	Mesogastropoda		Viviparidae	*Campeloma*	Adult	Campelomid snail	191
	Pulmonata		Planorbidae		Adult	Planorbid snail	18
	Pulmonata		Physidae	*Physa*	Adult	Physid snail	228
	Sorbeoconcha		Hydrobiidae	*Amnicola*	Adult	*Amnicola* snail	314
Zooplankton	Calanoida				Adult	Calanoid copepod	6
	Cladocera		Bosminidae	*Bosmina*	Adult	Waterflea	27
	Cladocera		Daphniidae	*Daphnia*	Adult	Waterflea	12
	Cladocera		Sididae	*Diaphanasoma*	Adult	Waterflea	27
	Cladocera				Adult	Waterflea	1
	Cyclopoida				Adult	Cyclopoid copepod	6
	Phylum: Rotifera				Adult	Rotifer	6
	Subclass: Copepoda				Larval	Copepod nauplius	3
	Subclass: Copepoda				Adult	Copepod	6
Terrestrial (Miscellaneous)	Araneae				Adult	Spider	205
	Coleoptera				Adult	Beetle	53
	Coleoptera				Larval	Beetle	62
	Collembola				Adult	Springtail	51
	Diptera				Adult	Other dipteran	153
	Diptera		Drosophilidae	*Drosophila*	Adult	Fruit fly	6
	Diptera		Ceratopogonidae		Adult	Gnat	285
	Diptera		Muscidae		Adult	Housefly	123
	Diptera		Chironomidae		Adult	Midge	695
	Diptera		Cuculidae		Adult	Mosquito	458
	Diptera		Ichneumondiae		Adult	Ichneumonid wasp	200
	Ephemeroptera				Adult	Mayfly	3
	Homoptera		Aphididae		Adult	Aphid	6
	Homoptera		Cicadelliae		Adult	Leafhopper	17
	Homoptera				Adult	True Bug	14
	Hymenoptera		Formicidae		Adult	Flying ant	117
	Hymenoptera		Formicidae		Adult	Ant	342
	Hymenoptera		Halictidae		Adult	Sweat bee	6
	Ixodida				Adult	Tick	294
	Lepidoptera				Larval	Catepillar	3
	Trichoptera				Adult	Caddisfly	9
Terrestrial seeds	Fagales		Betulaceae	*Betula*	Seed	Birch tree seed	2,931
	Rosales		Ulmaceae	*Ulmus*	Seed	Elm tree seed	3,596

isms boaters transport, and the effectiveness of various boat cleaning techniques. Our hope is that these data will inform improved risk management of AIS spread.

We found that organisms that are evolutionarily and morphologically similar to AIS in the Great Lakes region (e.g., Eurasian watermilfoil, spiny waterflea, and *Echinogammarus ischnus*) are being transported on small-craft boats and trailers (Table 4). Because we did not specifically target lakes known to have multiple invaders (only one of the two study lakes was known to harbor one invasive species—spiny waterflea), it was not surprising that we did not sample any animal or plant AIS. We did however sample several taxa similar to invaders known to be spreading in the region, e.g., spiny water flea and New Zealand mud snail, including the cladoceran *Diaphanosoma* spp. and several types of aquatic gastropods (e.g., hydrobids and physids). We also collected amphipods in our filter samples, suggesting that the non-native amphiphod *Echinogammarus ischnus* that is currently in the Great Lakes could be spread to inland lakes by boaters.

Figure 3. Results of experimental removal of biological materials from boat and trailer via boat washing or visual inspection. Panel A shows removal of *Myriophyllum spicatum* with different wash pressures and durations, and with visual inspection and hand-removal. Panel B shows data from the same treatments for the removal of small-bodied organisms.



Similarly, no invasive macrophyte species were collected from boats during our field survey, but the species we collected were representative of common aquatic vegetation communities in Northwoods lakes (e.g., *Vallisneria americana*, *Potamogeton gramineus*, and *Ceratophyllum demersum*; Wagner et al. 2007). As with small-bodied AIS, we would have been surprised to collect any invasive macrophytes, such as *M. spicatum*, in our samples, because the lakes where we washed boats were not known to contain invasive macrophytes. This expectation applied also to arriving boaters, because none of the nearby lakes (i.e., within 15 mile radius) had invasive macrophyte populations that were not under chemical control. If we had been working on a lake with a population of *M. spicatum*, it is highly likely that we would have found milfoil on boats, perhaps in even greater quantities than the native vegetation we found, given the tendency of *M. spicatum* to form dense mats of vegetation on the water's surface, enabling entanglement on boats (Smith and Barko 1990). Nevertheless, the native vegetation we found on boats is a useful surrogate for demonstrating the propensity of small craft to transport aquatic vegetation over land.

Despite many years of campaigns to educate boaters on how to avoid transporting organisms, our results demonstrate that overland transport of aquatic organisms by boaters still occurs frequently. If relatively diffuse educational campaigns stimulated boaters to take responsibility for their own boat hygiene, it would be a relatively inexpensive way to save the public the expense of equipment and employees required to clean boats. However, our data on self-reported cleaning rates and our observations of organisms attached to boats and trailers suggest that existing and previous education campaigns have not resulted in consistently high cleaning rates by boaters or in the use of highly effective cleaning practices in the Great Lakes region.

In Michigan and Wisconsin, states where educational efforts have been among the most vigorous in the United States, more than two-thirds of the boaters who responded to our surveys via mail and in-person do not always clean their boat when moving to another waterway, and more than a quarter of mail survey respondents reported not always removing aquatic weeds when they see them attached to their boat or trailer. This is not highly surprising in that social marketing research indicates that rates of behavioral change are relatively low in cases where compliance benefits society, but the individual who is being asked to take action receives little or no immediate benefit or gratification, particularly when the desired action is inconvenient to the individual (McKenzie-Mohr 2000). As this is the situation with boat cleaning, it is likely that to achieve high compliance rates educational efforts will need to be augmented with staffed cleaning stations placed at strategic locations and, possibly, enforcement and disincentives for non-compliance (i.e., fines). Two U.S. states in the Great Lakes region have already enacted laws making it illegal to launch a boat if there are potentially invasive aquatic species attached to the boat, trailer, or other equipment (Wisconsin Act 16, Section 30.715; Minnesota Statute 84D). Enforcement of these laws, however, remains a challenge and the strategic deployment of boat cleaning and inspection stations could be an efficient way to help increase compliance substantially. Our findings suggest that educational campaigns should continue to emphasize inspecting and cleaning boats and trailers when departing from a waterway and that cleaning stations and inspection crews should be deployed at sites where AIS are known to be present.

Our experimental results can help guide decisions about the kind of inspections and boat cleaning that may be most appropriate to a given situation. Understanding species' characteristics that affect their removal rates from boats and trailers is an important factor in selecting effective cleaning techniques. We found that transport of high-risk macrophytes can be prevented with a high probability through visual inspection and hand removal. However, visual inspection failed to detect small-bodied organisms, seeds, and resting stages of other species. Examples of small-bodied organisms in the Great Lakes region include the spiny and fish-hook waterfleas, *Bythotrephes longimanus* and *Cercopagis pengoi*, respectively, or even smaller, the deadly fish pathogen VHSv. If the spread of such small biological materials and organisms is a concern, visual inspection will not provide detection and removal with high probability. Alternatively, high-pressure washing can remove over 90% of small-bodied organisms, making it the most effective option we examined for preventing the transport of small organisms. The failure of visual inspection to detect a high percentage of small-bodied organisms is not surprising, but it is troubling because visual inspection of incoming boats and trailers is the most common type of government-sponsored or volunteer-organized intervention employed at boat ramps in the Great Lakes region (i.e., boat washing facilities are currently rare). During our field inspections of boats, we observed that, aside from the discovery of macrophytes, it was rare to find clear visual clues that small-bodied organisms might be attached to a boat or trailer (e.g., mud or foam deposits). Thus, it is unlikely that visual inspections under field conditions will discover and prompt removal of small-bodied organisms at a rate any higher than the ~63% rate in our experimental trials.

A limitation of our study that may have contributed to an overestimate of the effectiveness of all boat hygiene methods was our focus on techniques to clean only boat hulls and trailers. We did not sample the interior surfaces or standing water in boats. These surfaces and water reservoirs include carpets, live wells, bait buckets, and bilge water, all of which probably harbor AIS, especially small-bodied organisms. In fact, spiny waterflea have been found in bilge water samples (J. Muirhead, University of Alberta, pers. comm.). The release of bilge and live well water from lakes infected with VHSv into uninfected lakes may be a key vector in the spread of this deadly fish pathogen (Wisconsin Natural Resources Rule FH-40-07(E)). The prevalence of transport of VHSv and other pathogens in water held in boats merits further investigation, as does the effectiveness of washing in removing pathogens from the exterior and interior of boats. Additionally, in our experiment, we used only one model of boat and trailer. Boats and trailers vary in how difficult they are to clean, so our percent removal rates for given levels of effort do not necessarily represent what the removal rates would be for all boats and trailers. That said, our boat and trailer set up was relatively simple and would be in the lower range of cleaning difficulty. Thus, the percent removal rates we report are likely in the upper range of what can be achieved for the levels of cleaning effort we applied.

Efficient risk management of the spread of AIS by small-craft boaters requires determining if any sub-groups of boaters pose a disproportionately greater risk of transporting organisms among waterways. Our surveys indicated the existence of three different categories of boaters, for which management attention might appropriately differ. First, the majority of boaters (mail survey: 58%, in-person survey: 68%) keep their boat on the same body of water during the entire boating season and, therefore, pose a minimal threat for the overland spread of AIS. Second, in both the mail and in-person surveys, transient boaters reported visiting approximately three different waterways during a two-week period of the boating season, indicating a higher probability of AIS spread. Third, the professional fishing guides we surveyed reported visiting an average of more than five different waterways every two weeks. These data suggest that fishing guides pose the greatest risk of AIS spread, especially because they did not employ effective boater hygiene practices at a higher rate than other boaters. Focused efforts to ensure the inspection and cleaning of these most frequently moving boats—which may be analogous to superspreader individuals, i.e., individuals with many topological connections on the transmission network, in the human disease context (Riley 2007)—would likely pay high dividends in slowing AIS spread.

Our findings lead to two major management recommendations to slow the spread of AIS from the Great Lakes to inland waterways and among inland waterways in the region. First, we suggest increased management attention to identify and communicate with high-risk boaters. Such outreach would require more targeted efforts than the broad educational campaigns that have been employed previ-

Table 4. Nonindigenous species established in the Great Lakes that are morphologically similar to species collected in boat washing samples are listed. Species in bold are recognized as potentially important invaders.

Morphological category/ description	Selected nonindigenous taxa in Great Lakes	Representative taxa collected in boat washing samples
Plankton	***Bythotrephes longimanus* (spiny waterflea), *Cercopagis pengoi* (fish-hook waterflea),** *Daphnia galeata galeata*, *Daphnia lumholtzi, Eubosmina coregoni, Eubosmina maritime,* Copepods (5 spp.), Diatoms (17 spp.), Green alga (4 spp.)	*Bosmina* spp., *Daphnia* spp., *Diaphanasoma* spp., Rotifers, Copepods
Small benthic crustaceans and macroinvertebrates	***Echinogammarus ischnus, Hemimysis anomala* (bloody-red shrimp),** *Gammarus tigrinus*	Amphipoda, Isopoda,
Small benthic mollusks	***Potamopyrgus antipodarum* (New Zealand mud snail), *Dreissena polymorpha* (zebra mussel), Dreissena *rostriformis bugensis* (quagga mussel), *Corbicula fluminea* (Asiatic clam),** *Viviparus georgianus, Valvata piscinalis, Bithynia tentaculata, Sphaerium corneum, Pisidium henslowanum, Pisidium supinum, Cipangopaludina chinensis malleata, Pisidium amnicum, Pisidium moitessierianum, Elimia virginica, Gillia altilis*	*Campeloma* spp., *Physa* spp., *Amnicola* spp.
Other benthic organisms	Oligochaetes (6 spp.: *Branchiura sowerbyi, Gianius aquaedulcis, Potamothrix bedoti, Potamothrix moldaviensis, Potamothrix vejdovskyi, Ripistes parasita*)	Oligochaetes
Macrophytes	***Potamogeton crispus* (curlyleaf pondweed), *Myriophyllum spicatum* (Eurasian waterfoil),** *Hydrocharis morsus-ranae* (European frogbit), *Cabomba caroliniana* (fanwort)	*Vallisneria americana*, *Potamogeton* spp., *Ceratophyllum demersum*, *Myriophyllum heterophyllum*

Visual inspections of boats, motors, and trailers as they leave infested sites are important for slowing the spread of aquatic invasive plants.

ously. Our survey data suggest that professional fishing guides are one sub-group of small-craft boaters that move among waterways with extraordinary frequency and who currently employ less-than-ideal boat cleaning practices.

Second, we suggest that managers develop and use knowledge of the geographic location of invasive species within a region to inform efforts to manage the risk of future spread. Indeed, landscape-level approaches are increasingly recognized as highly important for effective management of natural resources, particularly aquatic ones (Post et al. 2008; Drury and Rothlisberger 2008; Vander Zanden and Olden 2008). For example, our experimental results suggest that knowing which lakes contain small-bodied AIS versus which contain only invasive macrophytes could guide the type of boat cleaning strategy employed to keep organisms from being transported away from already invaded lakes. In the Great Lakes region there are particular locations where high-pressure washing would be most useful. Such sites include (1) high-traffic boat landings on the Great Lakes (e.g., landings near major cities such as Green Bay, Cleveland, Chicago, and Toronto) which contain numerous small-bodied AIS (e.g., *Bythotrephes*, *Hemimysis*), (2) inland waterways currently invaded with spiny waterflea (e.g., Lake Gogebic, Michigan; Gile Flowage, Wisconsin), and (3) waterways where VHSv is known to occur (e.g., Lake Winnebago, Wisconsin). Inland waterways that harbor only invasive macrophytes could be effectively managed with visual inspection and hand removal of plants at boat landings.

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High-pressure washing of boats and trailers is a highly effective way to remove small-bodied organisms, but is no more effective than visual inspection and hand removal of aquatic plants.

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COLUMN:
GUEST DIRECTOR'S LINE

Hello from the Fish Culture Section!

Jesse Trushenski

Trushenski is an assistant professor at the Fisheries and Illinois Aquaculture Center, Southern Illinois University, Carbondale, and can be contacted at saluski@siu.edu.

Mike Barnes, Arden Trandahl, Jesse Trushenski, Carlos Martinez, Jim Bowker, and Steve Brimm are pictured in front of the replica ice house which houses the Fish Culture Hall of Fame at the D. C. Booth Historic National Fish Hatchery, Spearfish, South Dakota.

NOTE: AFS started as an association of fish culturists back in 1870. It is wholly appropriate, therefore, that this new series of Guest Director's Lines emphasizing the achievements and activities of our Sections commences with a report from the Fish Culture Section, which in recent years has been experiencing quite a revival. Other Sections will be invited to make similar occasional reports.—GNR

The Fish Culture Section (FCS) is concerned with advancing cultivation technology of aquatic organisms for food, recreation, habitat enhancement, and conservation. The Section disseminates information about fish culture to professionals and the lay public and strives to support and enhance fish culture programs of private, governmental, and international entities. Whether you raise food-fish on a commercial farm or endangered species in a federal hatchery, whether you drive a hauling truck or a desk, whether you work in ponds or an analytical lab, the FCS is where you go to learn, share, and interact with others doing what you do—fish culture. To fulfill this mission, we have recently undertaken a number of projects to serve our members and fish culturists everywhere.

One of the most visible projects the Section has been involved in is the development and distribution of the Guide to Approved Drugs for Use in Aquaculture, a quick reference poster that describes all of the currently approved therapeutants, spawning aids, and marking agents and how they can be used to treat fish. This poster came about in response to a call for help from fish culturists unsure about how they could use aquatic animal drugs effectively and legally. To answer this call, the FCS partnered with the U.S. Fish and Wildlife Service Aquatic Animal Drug Approval Partnership Program, the U. S. Food and Drug Administration's Center for Veterinary Medicine, as well as the AFS Fish Health Section, to produce and distribute these posters to culturists free of charge. To date, more than a thousand posters have been distributed to public hatcheries, academic and research institutions, and private fish culture ventures in the United States and abroad. As a result of the success of the poster, we now have a number of similar products in development—practical tools to put critical information in the hands of those that need it.

As some of you may know, AFS hosts seminars in Washington, D.C., to provide an opportunity for congressional staffers to learn about issues in fisheries science. Normally, AFS puts on a single seminar, but at the Section's urging, AFS will be making arrangements for two congressional briefing seminars this spring—one on fish habitat, and another dedicated to fish culture. Specifically, the FCS is planning to sponsor briefings addressing:

(1) needs in fish nutrition and aquafeeds,

(2) advances in hatchery-based marine fisheries enhancement, and
(3) the need for additional approved drugs for fish culture.

I will be flying the FCS colors when I head to DC to give a briefing on status and needs in fish nutrition and aquafeeds as a part of the National Coalition for Food and Agriculture Research seminar series. Ken Leber, Lee Blankenship, Reg Blaylock, and others have brought together a diverse and highly experienced group to address the marine stock enhancement subject on behalf of the FCS and the U.S. Aquaculture Society. Randy MacMillan and Jim Bowker have stepped up to represent the FCS Working Group on Aquaculture Drugs, Chemicals, and Biologics and tackle the briefing on aquaculture drugs.

While we're on the subject of Washington, D.C., policy, and politics, I should mention the effort that the Section has initiated in cooperation with the AFS Resource Policy Committee. Currently, there is only one sedative/anesthetic that is legal for use in food fish or fish that may be caught and consumed: MS-222, when used in accordance with the label claim on fish that are held for 21 days prior to consumption or release. For many applications, these conditions cannot be met. Although CO_2 gas can also be used as a sedative, this is not always a viable option. The fisheries profession needs access to an approved, effective, immediate-release sedative, and the FCS has initiated the development of an AFS Policy Statement to address this issue. AFS Policy Statements are documents that set forth sound, science-based arguments in support of the Society's particular position on a topic or recommended action. An expert panel—FCS President Elect Jim Bowker, Christopher Guy, James Garvey, Roy Yanong, Jeffrey Hill, Steven Cooke, Mary Fabrizio, Steve Sharon, Dave Erdahl, Randy MacMillan, and myself—has been charged by the AFS Resource Policy Committee and Society President Don Jackson with developing a Policy Statement on the need for an immediate-release sedative on behalf of the Society. A detailed outline has been developed, and the panelists are working hard to flesh out the full document. We are hopeful that what we produce will ultimately be accepted by the AFS membership and help make an immediate-release sedative available to fisheries professionals sooner rather than later.

Recently, members of the FCS leadership had the opportunity to visit the Fish Culture Hall of Fame at the D. C. Booth National Historic Fish Hatchery in Spearfish, South Dakota. I was joined by President Elect Jim Bowker, and Past Presidents Mike Barnes and Curry Woods (via teleconference). The D. C. Booth Hatchery is an impressive facility, and the Hall of Fame is a great testament to those who have made significant contributions to the field of fish culture. In prior discussions with Mike and D. C. Booth Hatchery Director Carlos Martinez, several ideas came up to improve the Hall of Fame and make it more interactive and more broadly representative of what fish culture was, is, and will be. So we descended on the Spearfish area to meet with Carlos and others associated with the Hall of Fame, see the facilities, and come up with a plan to make the improvements happen. Mike, Jim, Carlos, and I had an opportunity to sit down with retired D.C. Booth Hatchery Director Steve Brimm; executive director of the Booth Society, Eric Davis; and retired D.C. Booth Hatchery Director and charter President of the FCS, Arden Trandahl—as far as fish culture knowledge and experience, it was standing room only! At the end of the meeting, we came away with some concrete plans for improvements and proposals to secure the funds needed to make them a reality.

Programming is an important service the Section provides to our members and the parent Society. Over the past several years, the FCS has organized numerous symposia in cooperation with numerous partners, and this year is no exception. Every three years, the FCS partners with the U.S. Aquaculture Society and the National Shellfisheries Association to host the triennial AQUACULTURE conference, the largest professional meeting of fish culturists in the world. The FCS has contributed greatly to the 2010 triennial program, including a range of special symposia:

Advances in Larval Feed: Nutrition, Formulation, and Manufacture (chairs Charles Mischke and G. Joan Holt),
Cultured Aquatic Animals: Use and Implications for Stock Enhancement, Fisheries Management, and Species Diversity (Ken Leber, Kim Scribner, Mike Denson, Max Mayeaux, and Jesse Trushenski),
Nutriceuticals in Fish Health Management (Delbert Gatlin and Ann Gannam),
Advances in Broodstock Management and Spawning Aids Forum (Heidi Lewis and Jesse Trushenski),
Lipids in Aquaculture Nutrition and Physiology (Jesse Trushenski, Rebecca Lochmann, Ron Hardy, and Giovanni Turchini),
Meeting Production Goals with Limited Resources (Jim Bowker and Jesse Trushenski),
Culture of Imperiled Species (John Seals and Chester Figiel),
Physiological Insights II (Kurt Gamperl, Curry Woods, John Rise, and Brian Small), and
Therapeutic Drugs (Jim Bowker and Dave Straus).

The Section also contributes to the program of AFS Annual Meetings. This year, with help from fellow organizer Brian Wisner and co-chairs Karin Limburg, Bill Richkus, and Larry Miller, Jim Bowker has developed a special symposium for the AFS 2010 meeting in Pittsburgh entitled, "Restoration of American Shad and River Herring in Atlantic Coastal Waters." The FCS is sponsoring this symposium with the Fisheries Management Section to address culture and management efforts dealing with these important species. These symposia will give conference attendees an opportunity to share and learn the most up-to-date information in each of these topical areas.

It's cliché but true, many hands makes for light work—thanks to our active and engaged members, we're getting a lot accomplished for the Section and fish culturists everywhere. But there's always more to be done—got an idea or just want to pitch in? Drop me a line at saluski@siu.edu!

Continued from page 108

crayfishes (Cambaridae) allow these fishers to be fairly opportunistic.

These are people living metaphorically in the "hypolimnion" in our society. Up in the "epilimnion" there is light and warmth. The epilimnion is where nutrients tend to circulate. Subsequently, and as long as stratification persists, most production, in an economic sense, occurs in society's epilimnion. There isn't much mixing with the hypolimnion or interactions with the denizens therein. The hypolimnion, by contrast, is colder, darker, more acidic, and generally dependent energetically on the detritus that rains down from above. Sometimes the dynamics of energy flow and production in the epilimnion can become so extreme that it blocks the light, keeping it from even reaching the hypolimnion. The result can be hypoxia or anoxia in these deeper realms. Conditions for life in the hypolimnion deteriorate accordingly. Production in the hypolimnion also tends to be restricted to times when complete mixing occurs. This mixing can be gradual and seasonal, but sometimes there can be storms that cause untimely turnovers, which in turn can negatively impact all life in the system. The hypolimnion can be a tough place to live. I know. I lived for a while on the streets.

I have also lived and worked in Alaska, and am very familiar with the issues of subsistence fishing there. Ditto for other wild and wooly places around the world. But I can tell you that subsistence fisheries are not restricted to wilderness. I've worked with subsistence fisheries in Gatun and Bayano lakes down in Panama, and in numerous reservoirs, rivers, and lakes in the Dominican Republic. These are not wilderness areas. They're really more like the high-density rural areas where I live and work here in Mississippi. I've worked with subsistence fisheries in the main stem of the lower Musi River where it flows through the huge city of Palembang (Southern Sumatra), Indonesia, and with subsistence fisheries of Lake Victoria just outside of Kampala, Uganda.

Throughout North America, subsistence fisheries (call them what you will, but that's what they are), can be found in our backyards, scattered across fairly settled landscapes, and in the middle of our cities. I am aware that there is subsistence fishing in the Potomac River just outside of Washington, D.C., and in New York City's East River. I've seen it in a lake located beside the Fine Arts Center in Little Rock, Arkansas, and in suburban lagoons just southeast of San Juan, Puerto Rico. A recent feature on National Public Radio (Glen Moberg, 31 January 2010) addressed subsistence use of fish captured by people engaged in ice fishing on Wisconsin's Lake Wausau. Subsistence fishing is out there, folks. We don't talk much about it in most parts of North America. It could be a little bit embarrassing to some people. But it is there.

The point here is that there are people in North America who have very direct dependencies on fish that they catch and we are very probably going to see more of this in the future. I am not advocating dramatic reorientation of what we all do in our many and varied fisheries professions. Far from it. We contribute best when we do what we do best: good science and its thoughtful application. But what I am suggesting that each of us do is to step back from our work, from concerns about uncertain futures, from the safe places we may have created for ourselves…just for a little while…and take a hard look at the world that is evolving around us, including the hypolimnion. The economic uncertainties of the day are giving us an opportunity to regroup, rethink, reflect, and reconnect with something beyond bio-political, economic, and academic arenas… beyond knowledge, beyond understanding. They are giving us a chance to re-discover and perhaps confirm "meaning" in our professions, individually—how we focus our careers in fisheries to reach out with a positive touch to the world—the fundamental core of our professional identities. It is a chance to take a very deep breath and confirm who we are and what we are all about. These times are, in essence, a treasure of sorts. They give us a chance to "put the trash where it belongs," "weed the garden," "fix the screen door," and give some thought, time, and energy to people and fisheries around us that we may have, albeit unintentionally, neglected or overlooked for awhile.

It is a wonderful thing to live and work in the epilimnion and understandably, when times are tough (as they are now), we increase the intensity of our efforts to stay in it. We focus on the nekton moving about in the epilimnion, seeking new ways of engagement in order to shore up our own energy reserves. We need the energy we get from the nekton so that we too can keep going. We need those grants. We need those contracts and sponsorships. We need funding in institutional and agency budgets. We need sales and memberships. We understandably emphasize elements that define the epilimnion because the nekton that swims there relates best to them, (e.g., the politically and economically important recreational and commercial fisheries and allied industries that support them). But let us not forget the hypolimnion. It also needs and deserves our attention. It lets us know this occasionally by internal seiches but it will not shout for our attention. The hypolimnion's ways are deeper, quieter…but its enduring song resonates throughout all strata. And let us not forget that the hypolimnion is the foundation upon which the epilimnion rests.

REFERENCE:

Mobert, G. 2010. Wisconsin ice fishers feel the recession's chill. National Public Radio. "Weekend Edition" 31 January 2010. Available at: www.npr.org/templates/story/story.php?storyId=123113320.

CANDIDATE STATEMENT: SECOND VICE PRESIDENT

All AFS members will receive an e-mail with instructions on how to vote online.

Robert L. Curry

BACKGROUND

Robert L. Curry is the chief of inland fisheries for the North Carolina Wildlife Resources Commission. He received his B.S. in biology from Augusta College and his M.S. in fisheries and wildlife science from the University of Tennessee. Curry began his career in 1984 as a technician and two years later he became the statewide warmwater fish production coordinator. Curry was promoted to assistant chief in 1994; 10 years later he was promoted to division chief.

Curry spent much of his field time sampling reservoirs and small lakes. He quickly transitioned into warmwater fish production and orchestrated the transfer of the state's warmwater production facilities from a 15-surface acre facility constructed in the 1920s to a modern facility with 43 ponds totaling 45 surface acres. As assistant chief, he managed the division's research, survey, management, and angler access programs. Most recently, Curry has focused on protecting species of special concern and their habitats, integrating traditional sportfish and nongame fisheries research and management, implementing urban and community fishing programs, and revitalizing fish production facilities.

AFS INVOLVEMENT

Curry is an active member of the North Carolina Chapter, chaired its Education Committee, and later served as Chapter president. He served on the Southern Division's Striped Bass Committee and was the registration chair for the 2003 mid-year Southern Division meeting. Curry was president of the Southern Division and chaired the AFS Disaster Relief Effort. At the Society level, Curry served on several AFS committees—Local Arrangements, Outstanding Chapter Award, Time and Place, Nominating, Membership Concerns, and Management—and he currently chairs the Meritorious Service Award Committee. Curry was the general chair of the 1999 AFS Annual Meeting in Charlotte, North Carolina. He is a member of the Fish Culture and Fisheries Management Sections and he is currently president of the Fisheries Administration Section. An AFS member since 1979, Curry received the AFS Distinguished Service Award in 2007 for his part in overseeing the AFS Disaster Relief Effort.

VISION

The American Fisheries Society is the world's oldest scientific organization dedicated to advancing fisheries science, strengthening fisheries professionals, and conserving fishery resources. Our rich and diverse history demonstrates our commitment to accomplish our mission effectively by providing many forums for the exchange of high-quality science, including world-renowned publications; promoting professional development through a variety of membership services; mentoring future fishery professionals; and providing sound, science-based recommendations to improve the sustainability of aquatic ecosystems.

The Society has revised its strategic plan but we need to continue to evaluate our strategies and be prepared to adapt to rapidly changing environments. As we face the onslaught of significant physical and economic changes, we and our successors need to address global climate change, exponential population growth, and significant loss of critical aquatic habitats. One of the Society's greatest strengths is our commitment to mentoring future leaders—our young professionals and students—who will be crucial to ensuring sound, science-based management and conservation of aquatic resources and habitats. The Society should not neglect its responsibility to take the lead in preparing these future leaders. Rather, we should continue to encourage their active involvement in the Society and enhance their professional development. We must also continue to provide quality services to our professional membership by maintaining high quality publications, meeting forums, and other opportunities for professional growth.

The Society's greatest asset is its Unit structure; those members who volunteer to lead the Sections, Divisions, and Chapters are the heart of AFS. Society officers must nurture our Units, provide them with the tools necessary to advance our mission, and empower them to move forward at the local level. They are vital to implementing strategies that will conserve and protect aquatic habitats and ensure viable and sustainable fishery resources into the future.

AFS is known throughout the world as a leader in fisheries science and in communicating information through peer-reviewed scientific publications, workshops, and meetings. We most often share our science and recommendations with those we are comfortable dealing with—other scientists. We should investigate opportunities to expand our relevance beyond just the fisheries community. The Society has done a remarkable job in the past few years engaging Congressional leaders and informing them about critical aquatic resource issues; we must continue that effort.

We can improve our involvement and engagement with other natural resource conservation organizations, such as the Association of Fish and Wildlife Agencies (AFWA) as well as industry partners. State agency directors are actively involved with AFWA and rely on it to represent states' fish and wildlife interests in Congress. By re-engaging our relationship with AFWA, we can ensure that critical aquatic resource issues receive the attention of state directors who make resource management decisions and allocate funding to support aquatic resource management.

I am truly humbled to have an opportunity to give back to the organization that has given so much to me. If elected, I pledge my commitment to represent our membership and our profession to the best of my ability.

CANDIDATE STATEMENT: SECOND VICE PRESIDENT

All AFS members will receive an e-mail with instructions on how to vote online.

Robert M. Hughes

BACKGROUND

Education: Ph.D. Oregon State University; M.Sc. and A.B. Michigan. Employment: Oregon State University; Federal University of Minas Gerais; and Amnis Opes Institute; conducted research for the U.S. Environmental Protection Agency (USEPA) for 32 years through Oregon State, Dynamac, ManTech, Illinois, USEPA, and Western Michigan University; assistant professor Western Michigan University; high school science teacher.

My research focused on fish assemblage assessment in streams, lakes, and rivers across large geographic extents in the United States, Europe, Brazil, and India. I developed aquatic ecosystem indicators for the USEPA's Environmental Monitoring and Assessment Program (EMAP), which contributed to the first statistically-rigorous national assessments of U.S. surface waters. I field-tested the ecoregion concept leading to the USEPA's national ecoregion map. I have authored over 100 peer-reviewed publications, been a sponsored participant in eight national workshops on large rivers and bioassessment, and have been a guest speaker in Europe, South America, Australia, and China. I have received 6 EPA publication awards, a best paper in *TAFS* Award, two Fulbright Awards, the North American Benthological Society's Environmental Stewardship Award, and the ManTech President's Award for Excellence. I was an external reviewer for the State of the Nation's Ecosystems Report, European Fish Index, Great Lakes Environmental Indicators, and National Research Agency of France. I am a member of Oregon's Independent Multidisciplinary Science Team, which reviews state actions for rehabilitating salmon and watersheds.

AFS INVOLVEMENT

Oregon Chapter (ORAFS): president elect 1993–1994, president 1994–1995, past president 1995–1996. Western Division (WDAFS): program chair 1996, vice president 2004–2005, president elect 2005–2006, president 2006–2007, past president 2007–2008, chair of Environmental Concerns Committee 2008–2010. Parent Society: Water Quality Section (WQS) president elect 1997–1999, president 1999–2001, past president 2001–2003, newsletter editor 2001–2004; chair of AFS Nominating Committee 1999–2000; member of Resource Policy Committee 1999–2000, 2010; member of Nominating Committee 1998–2000, 2008–2009; Governing Board 1999–2001, 2005–2007; Management Committee 2005–2007; Distinguished Service Award Committee 2007; Economic Policy Task Force 2008; Outstanding Chapter Award Committee 2008; associate editor *NAJFM* 2001–2003; chaired 9 symposia at Annual Meetings.

My major accomplishments as an ORAFS officer included completion and passage of a professional ethics statement, placing ORAFS on a secure fiscal basis, funding and hiring a professional legislative liaison, and compiling and implementing an annual meeting guidebook. As a WDAFS officer I helped to ensure the profitability of four annual meetings through fund raising, review NMFS' Columbia River management plans, form a Mexico Chapter, dissolve four non-functioning Chapters, and introduce a resolution supporting review of the Pebble Mine in Alaska's Bristol Bay drainage area. As a WQS officer, I transformed our newsletter from paper to electronic at a substantial cost savings, wrote letters concerning ammonia and biological criteria to USEPA, and drafted a resolution on population and economic growth.

VISION STATEMENT

I supported fiscal responsibility in all my past AFS positions and still do. Conservative and balanced investing, income generation, and expenditures are essential to a successful and sustainable Society. I will coordinate with the Management Committee and executive director to ensure that AFS remains on a secure financial footing.

AFS must stay abreast of changes in electronic communications, including publication of its journals and alternative cost structures for its authors and subscribers to compete better with corporate publications. I favor using webcasts to expand portions of our Annual Meetings to a wider professional and public audience, especially those that cannot afford to attend in person or who choose to reduce their carbon footprints. I will work with the executive director, Electronic Services Committee, Publications Overview Committee, and Fisheries Information and Technology Section to seek ways to communicate less expensively, faster, and more widely.

I favor improved science communication to the North American public. Communicating AFS positions, particularly the science behind them, to North American legislators and administrators must be a continuous practice if AFS is to have an effective voice in the political processes in our three nations. I favor increased public recognition of AFS members and Units who communicate our science to the public, especially students. Also, science-based educational web briefs and press releases based on key journal publications have considerable potential. I would like to help AFS develop a website publication for short peer-reviewed communiqués (similar to poster presentations), providing an outlet for the massive amounts of grey literature produced by our public fishery and aquatic resource agencies. I will collaborate with the executive director, the awards committees, Electronic Services Committee, Publications Overview Committee, Education Section, and the Fisheries Information and Technology Section to improve public outreach.

AFS is a leader in the World Council of Fisheries Societies and formed a Mexico Chapter. I believe there are substantial additional opportunities to expand our membership in South America, Europe, and Japan. I favor holding a joint meeting with the Brazilian Society of Ichthyology (over 1,000 members) in Brazil and a joint meeting in Europe, and reducing introductory membership and Annual Meeting fees to AFS members outside North America. I will work with the executive director, Governing Board, and International Fisheries Section to develop such initiatives.

CALENDAR: FISHERIES EVENTS

To submit upcoming events for inclusion on the AFS Web site Calendar, send event name, dates, city, state/province, web address, and contact information to cworth@fisheries.org. (If space is available, events will also be printed in Fisheries magazine.)

More events listed at www.fisheries.org

Mar 1-5	AFS	Aquaculture 2010 Conference	San Diego, California	www.was.org
Mar 25-27		Eighth Biennial Confrerence on University Education in Natural Resources	Blacksburg, Virginia	www.cpe.vt.edu/cuenr/index.html
Apr 8-9	AFS	AFS-The Wildlife Society Species Introductions and Re-introductions Symposium	Starkville, Mississippi	www.cfr.msstate.edu/wildlife/symposium
Apr 10		Oregon Council for the Social Studies Spring Conference: Journey on the Columbia River: Past, Present, and Future	Rainier, Oregon	www.oregonsocialstudies.org
Apr 22-23		Electrofishing Class	Vancouver, Washington	www.smith-root.com
Apr 25-27	AFS	Northeastern Division, joint with Northeast Fish and Wildlife Conference	Newton, Massachusetts	www.neafwa.org
Apr 26-30		16th Western Groundfish Conference	Juneau, Alaska	https://tundra.iphc.washington.edu
May 4-8		State of the Salmon: Ecological Interactions between Wild and Hatchery Salmon	Portland, Oregon	www.stateofthesalmon.org/
May 5-6		17th Annual Conference on the Great Lakes / St. Lawrence River Ecosystem: Protecting and Restoring Aquatic Ecosystems through Government and Community Action	Cornwall, Ontario, Canada	http://riverinstitute.ca/mailman/listinfo/conferencenews_riverinstitute.ca
May 23-26		Australasian Aquaculture International Conference and Trade Show	Hobart, Tasmania	www.australian-aquacultureportal.com
May 30-Jun 3	AFS	AFS Early Life History Section's 34th Annual Larval Fish Conference	Santa Fe, New Mexico	www.larvalfishcon.org
Jun 16-18		Offshore Mariculture Conference	Dubrovnik, Croatia	www.mercatormedia.com
Jun 20-22	AFS	Second International Catfish Symposium sponsored by AFS North Central and Southern Divisions	St. Louis, Missouri	www.catfish2010.org
Jun 21-24		International Symposium on Genetic Biocontrol of Invasive Fish	Minneapolis, Minnesota	www.seagrant.umn.edu/ais/biocontrol
Jul 7-12		Joint Meeting of Ichthyologists and Herpetologists	Providence, Rhode Island	www.dce.ksu.edu/conf/jointmeeting
Jul 25-30	AFS	Fisheries Society of the British Isles Conference: Climate Change and Fish	Belfast, Northern Ireland	www.fsbi.org.uk/events.htm.
Aug 1-6		95th Annual Meeting of the Ecological Society of America	Pittsburgh, Pennsylvania	www.esa.org/pittsburgh
Aug 15-20		Second International Conference on the Effects of Noise on Aquatic Animals	Cork, Ireland	www.aquaticnoise.org
Sep 8-11		Fish Sampling with Active Methods Meeting	Ceske Budejovice, Czech Republic	www.fsam2010.wz.cz
Sep 12-16	AFS	American Fisheries Society 140th Annual Meeting	Pittsburgh, Pennsylvania	www.wildtroutsymposium.com
Sep 22		World Ocean Council:Sustainable Ocean Summit	Honolulu, Hawaii	www.oceancouncil.org

Sep 22-23		Electrofishing Class	Vancouver, Washington	www.smith-root.com
Sep 27-28		Fourth International Natural Channel Systems Conference: Stream Corridors: Restoring Our Natural Infastructure	Mississauga, Ontario, Canada	www.naturalchannels.ca
Sep 28-30	AFS	Wild Trout Symposium	West Yellowstone, Montana	www.wildtroutsymposium.com
Oct 3-8		Aquatic Resources Education Association Biennial Conference	Omaha, Nebraska	www.areanet.org
Nov 8-11		Alaska Sea Grant Meeting: Ecosystems 2010 Lowell Wakefield Fisheries Symposium:Global Progress on Ecosystem-based Fisheries Management	Anchorage, Alaska	http://seagrant.uaf.edu/conferences/2010/wakefield-ecosystemb/index.php
Dec 12- 15	AFS	North Central Division, joint with Midwest Fish and Wildlife Conference	Minneapolis	www.midwest2010.org

COLUMN:
STUDENTS' ANGLE

Enhancing Graduate School Experience through Participation in Place-Based Education:

A Case Study of the Cape Eleuthera Island School/Cape Eleuthera Institute

Karen J. Murchie, Aaron D. Shultz, and Edd J. Brooks

Murchie is a Ph.D. candidate at the Fish Ecology and Conservation Physiology Laboratory at Carleton University and a member of the Flats Ecology and Conservation Program at the Cape Eleuthera Institute. Shultz is a Ph.D. candidate at the University of Illinois and a member of the Flats Ecology and Conservation Program at the Cape Eleuthera Institute. Brooks is a Ph.D. candidate at the University of Plymouth and is the Shark Program Manager at the Cape Eleuthera Institute.

In a graduate school setting, there often seems to be only a handful of ways to give back to science. These opportunities may include presenting findings in publications or at conferences, delivering a guest lecture, or acting as a teaching assistant for a class or laboratory. One can also become involved in outreach activities through professional societies such as AFS, but sometimes there are other opportunities out there that are not so apparent. For example, imagine the rewards involved in guiding a research team composed of junior and sophomore high school students through the scientific process in a semester-long experiential education program. The purpose of this article is to provide graduate students with an example of how they can enhance their grad school experience by teaching research at a place-based educational institution.

THE CAPE ELEUTHERA ISLAND SCHOOL AND CAPE ELEUTHERA INSTITUTE

The Island School (IS) was founded in 1998 to immerse international and local students into the environment and culture of South Eleuthera, The Bahamas. While the curriculum includes standard classes such as science, math, English, history, and art, non-traditional classes, like research, focus on the application of science-based knowledge to real world problems. To support and enhance the semester-long place-based experiential program, as well as successfully address relevant environmental issues facing The Bahamas and the Caribbean, the Cape Eleuthera Institute (CEI) was officially opened in 2005. With a 5,000 ft^2 flow-through seawater facility, dry laboratories, dormitories, and administrative office, the capacity to facilitate formal collaborations with universities was expanded. With CEI, graduate students now have the opportunity to conduct their own thesis research as well as teach the scientific process to high school students from the IS.

Field work includes learning how to use a seine net.

THE ISLAND SCHOOL RESEARCH PROGRAM

Research projects driven by in-house researchers and graduate students are often focused on ecology, anthropology, sustainable food production, and waste management. Each IS class consists of 48 students divided among eight specific research teams that range in topics from flats ecology, shark biology, archaeology, aquaculture, and aquaponics. Each team is led by one or two research advisors who guide the students through the scientific process. Students learn how to synthesize scientific literature, form a research question, design and execute an experiment, and communicate their findings through oral and poster presentations. Data management and basic statistical skills are taught and applied to the collected data, putting the students well ahead of most of their peers entering universities. Research advisors assess their students on all of the above assignments as well as a final oral assessment, which is of similar design to an oral defense for graduate programs. A symposium is held at the end of every semester (June and December) to showcase the research through poster presentations. During this event, the high school students present to their peers, locals, government officials, and visiting scientists. Graduate students can expect to meet scientists from their field of study and from other disciplines, which in turn can result in collaborative projects from universities throughout the world. In addition, the research symposium puts scientists in direct contact with Bahamian nongovernmental organizations and government officials that often use information collected by researchers to make management decisions.

Students learn to sample blood from a bonefish.

WHAT TO EXPECT

Since research is a flagship portion of the curriculum at the IS, a significant amount of time (up to nine hours of class time per week) are devoted to the program. This does not include marking and lecture preparation, and thus typically exceeds the usual teaching assistantship time requirements which one would normally encounter at a home institution. However, the extra time commitment is balanced by the enhanced teaching skills (e.g., lesson planning, student evaluation) developed by the grad student. An additional challenge for participating graduate students is teaching the high school-aged demographic. The benefit to this situation, however, is that your classroom is in a hands-on environment where it is much easier to connect the significance of the project to the young researcher. Also, graduate students have the opportunity to share their enthusiasm for research with the class. Instilling excitement and interest in students prior to university enrollment is more likely to encourage youth to pursue the sciences. Alumni of the IS often note that their research experience assisted them in choosing a major in a science-related field.

The flexibility of the research curriculum is a great advantage in the teaching environment at the IS, such that the individual project can be tailored to compliment or be a part of graduate thesis work. The ability to have additional help in the field can be particularly advantageous as graduate students sent to remote locales often lack field assistants due to the cost of lodging, etc. In fact, not only can students act as great technicians, but the involvement in the IS semester through teaching could help offset the expense of your individual research time at the field station. Stretching research funds a little further can only be a good thing (i.e., more conferences, field time, gear for your study, etc.). Perhaps the biggest challenges to the graduate student are reduced access to their supervisor and colleagues at their home institution for support, as well as financial considerations such as maintaining housing while away, missing teaching assistantships at home, and the inability to work in a foreign country for extra money. That being said, the benefits still outweigh the challenges.

HOW TO PARTICIPATE

Coupling primary research with the opportunity to mentor students in the scientific method can be an invaluable learning experience regardless of where the interactions occur. If you are going to be starting a graduate degree where your field research could take place in the sub-tropics, it might be worth considering CEI as your home base. Carleton University in Canada, the University of Illinois in the United States, and the University of Plymouth in the United Kingdom have all established a strong relationship with CEI by either sending graduate students from the home institution or supporting current research associates at CEI to conduct their graduate studies. If staying an entire semester is not feasible, you can still plug into the IS semester by conducting evening lectures, having students participate with research during their free time, or possibly as part of their science class. No matter how you get involved, interacting with high school-aged students and getting them excited about research in a hands-on environment is a rewarding experience any graduate student can appreciate. Check out www.ceibahamas.org for information on the institute and its facilities, and www.islandschool.org for more details on the IS program.

OTHER OPPORTUNITIES

Although we used a case study which focused on a single institution, there are many other opportunities in which graduate students can participate to enhance their educational experience and give back to the scientific community. These opportunities range from mini-courses or day-camps organized on university campuses to field expeditions. For example, many universities hold mini-courses (e.g., 5 days) during the summer semester where high school students can participate in focused programs run by graduate students and supervised by faculty. This is a great opportunity to inspire youth awareness in fisheries research and conservation by designing a course that will not only be stimulating to the students, but can tap into your area of interest and expertise. Another great way to pass on your fisheries knowledge to high school students is by mentoring a Hutton Junior Fisheries Program participant. Additional information of the Hutton program can be obtained at www.fisheries.org/afs/hutton.html. Consider as well the possibility of becoming a teaching assistant on a university field course. These typically short (e.g., two week) courses are a great opportunity to work with undergraduates in place-based learning environments, and they often have research components where graduate student input is invaluable. Regardless of what avenue you may choose to enhance your graduate school experience, the rewards are endless! So get out there and get involved!

ACKNOWLEDGMENTS

The authors thank Steven Cooke (Carleton University) and Andy Danylchuk (University of Massachusetts Amherst) for their guidance and feedback on this article.

Call for Award Nominations: 2010 American Fisheries Society Awards

The American Fisheries Society is seeking nominations and applications for several 2010 awards. Award recipients will be honored at the Annual Meeting in Pittsburgh, Pennsylvania, September, 2010. Nominations typically require a candidate's name, full contact information, biographical information, and/or history of service to the Society. Some awards require additional nomination materials. For more information on how to nominate an individual, or organization, see descriptions below or contact the award chair. You may also contact Gail Goldberg, AFS awards coordinator, at ggoldberg@fisheries.org, or 301/897-8616 X 201 for more information.

Award of Excellence

Presented to an AFS member for original and outstanding contributions to fisheries and aquatic biology. See awards page on website for important information.

Nomination deadline**:** 10 May 2010

Contact: Chair Anita Kelly,
akelly@uaex.edu
UAPB Fish Health Services
Lonoke Agricultural Building
PO Box 357
Lonoke, AR 72086
Phone:501/676-3124
Fax:501/676-7847

Carl R. Sullivan Fishery Conservation Award

Presented to an individual or organization for outstanding contributions to the conservation of fishery resources. Eligibility is not restricted to AFS members, and accomplishments can include political, legal, educational, scientific, and managerial successes.Nominations should include a synopsis of fishery conservation contributions; a description of the influence of those contributions on improved understanding, management, or use of fishery resources; and at least one additional supporting letter. Nominations may be submitted electronically via e-mail or as hard copy delivered by mail.

Nomination deadline: **16 April 2010**

Contact: Wayne Hubert,
whubert@uwyo.edu
Hubert Fisheries Consulting, LLC
1063 Colina Drive
Laramie, WY 82072
Phone: 307/760-8723

Excellence in Public Outreach

Presented to an AFS member who goes the "extra mile" in sharing the value of fisheries science/research with the general public through the popular media and other communication channels. Two or more individuals may act as nominators, but at least one nominator must be an AFS member. Entries must include a biographical sketch of the nominee (not to exceed 3 pages) and supporting evidence of communicating the value of fisheries issues/research to the general public through the media and other communication channels, plus any evidence of teaching others about communication with the public.

Nomination deadline: 5 May 2010

Contact: Tom Lang, toml@wp.state.ks.us
320 North Jackson Street
Pratt, KS 67124
Phone: 620/672-0722
Fax: 620/672-2972

Honorary Membership

Presented to individuals who have achieved outstanding professional accomplishments or have given outstanding service to the Society. Honorary Members must be nominated by at least 100 active members and elected by a 2/3 majority of active members online.

Nomination dateline: 1 May 2010

Contact: Gail Goldberg,
ggoldberg@fisheries.org
American Fisheries Society
5410 Grosvenor Lane, Suite 110
Bethesda, MD 20815

Meritorious Service Award

Presented to an individual for loyalty, dedication, and meritorious service to the Society throughout the years; and for exceptional commitment to AFS's programs, objectives, and goals.

Nomination deadline: 7 May 2010.

Contact: Chair Bob Curry,
robert.curry@ncwildlife.org
NC Wildlife Resources Commission
Division of Inland Fisheries
1721 Mail Service Center
Raleigh, NC 27699-1721
Phone: (919) 707-0221
Fax: (919) 707-0028

Outstanding Chapter Award

Recognizes outstanding professionalism, active resource protection, and enhancement programs, as well as a strong commitment to the mission of the Society. Three awards are given, one for small Chapters, one for large Chapters, and one for a Student Subunit of a Chapter. Chapters should submit an application to their Division presidents to be considered. Division presidents must nominate two best Chapters from their Divisions, one with less than 100 members and another with 100 members or more.

Applications can be obtained from the AFS website—see the main awards page for more information.

Nomination deadline: 1 June 2010.

Contact: Jessica Mistak,
mistakj@michigan.gov
DNR Marquette Fisheries Station
484 Cherry Creek Road
Marquette, MI 49855
Phone: 906/249-1611x308
Fax: 906/249-3190

President's Fishery Conservation Award

Presented in two categories: (1) an AFS individual or Unit, or (2) a non-AFS individual or entity, for singular accomplishments or long-term contributions that advance aquatic resource conservation at a regional or local level. The award is administered by the AFS Past President's Advisory Council. A nomination package should include a strong and detailed letter describing the nominee's contribution and the evidence for accomplishment at a regional or local level. If the nomination is for an individual, include a CV if possible. Nominations may be supported by multiple individuals by signing one nomination letter, or by submitting supporting letters in addition to the main nomination letter. Include the nominee's title and full contact information (address, e-mail, phone).

Nomination deadline: 10 May 2010

Contact: Bill Franzin, AFS Past President

Laughing Water Arts and Science, Inc.
1006 Kilkenny Drive
Winnipeg, MB, Canada R3T 5A5
Phone: 204/219-9018
E-mail: franzin@shaw.ca

William E. Ricker Resource Conservation Award

Presented to any entity (individual, group, agency, or company) for accomplishment or activity that advances aquatic resource conservation that is significant at a national or international level. The award is administered by the AFS Past President's Advisory Council. A nomination package should include a strong and detailed letter describing the nominee's accomplishments and the evidence for being "significant at a national or international level." If the nomination is for an individual, include a CV if possible. Nominations may be supported by multiple individuals by signing one letter, or by submitting supporting letters in addition to the main nomination letter. Include the nominee's title and full contact information (address, e-mail, phone).

Nomination deadline: 10 May 2010
Contact: Bill Franzin, franzin@shaw.ca
Laughing Water Arts and Science, Inc.
1006 Kilkenny Drive
Winnipeg, MB, Canada R3T 5A5
Phone: 204/219-9018

Retired Members Travel Award for the AFS Annual Meeting

The American Fisheries Society has established this travel award to encourage and enable retired members of the Society to attend Annual Meetings, particularly those members who might play a more active role in the meeting. The Society recognizes that some retired members who desire to participate in the Annual Meeting might be inhibited for financial reasons. Retired members may not have funds for travel to meetings that were available to them while employed. Therefore, this award is meant for those members who truly have a need for financial assistance. The Society has neither means nor desire to verify financial need, so that your request for support is based on an honor system. However, you must be a dues-paying retired member of the American Fisheries Society to apply. A maximum of $1,500 may be awarded for reimbursable expenses. See the main awards page for the application form on the AFS website.

Nomination deadline: 10 May 2010
Contact: Bill Franzin, franzin@shaw.ca
Laughing Water Arts and Science, Inc.
1006 Kilkenny Drive
Winnipeg, MB, Canada R3T 5A5
Phone: 204/219-9018

Student Writing Contest

Recognizes students for excellence in the communication of fisheries research to the general public. Undergraduate and graduate students are asked to submit a 500- to 700-word article explaining their own research or a research project in their lab or school. The article must be written in language understandable to the general public (i.e., journalistic style). The winning article will be published in Fisheries. Students may write about research that has been completed, is in progress, or is in the planning stages. The papers will be judged according to their quality and their ability to turn a scientific research topic into a paper for the general public and will be scored based upon a grading rubric. (Check the AFS web site on the main awards page for the grading rubric. For examples of past winning papers, see *Fisheries* 32(12):608 & 609 and *Fisheries* 34(1):39)

Submission deadline: 5 May 2010
Contact: Tom Lang, toml@wp.state.ks.us
320 North Jackson Street
Pratt, KS 67124
Phone: 620/672-0722
Fax: 620/672-2972

The Emmeline Moore Prize

The American Fisheries Society (AFS) has established a new career achievement award, named after the first female AFS president, Emmeline Moore (1927–1928), to recognize efforts of an individual member in the promotion of demographic diversity in the Society. This award will be presented to an individual who demonstrates strong commitment and exemplary service to ensuring equal opportunity access to higher education in fisheries and/or professional development in the broad range of fisheries science disciplines. Qualified nominees must exhibit clear evidence of service and commitment to diversity initiatives, including a strong research or fisheries management leadership background, public understanding of diversity issues, technical and popular writing, and inspirational leadership. Candidates should also have enunciated principles that lead to greater involvement of under-represented groups in fisheries science, education, research, or management. Nominees for the award are restricted to AFS members. A nomination package should include a detailed letter of support (maximum three pages) describing the nominee's accomplishments and including evidence of involvement in diversity initiatives given the criteria noted above. The main letter of nomination can be supported through several signatures or up to three additional letters of support can be submitted. Please include in the nomination letter, the nominee's title and full contact information (i.e., address, e-mail, phone etc.) to complete the package.

Nomination deadline: 31 May 2010
Contact: Larry A. Alade,
larry.alade@noaa.gov
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole Laboratory/
Population Dynamics
166 Water Street
Woods Hole, MA 02543
Phone: 508/495-2085
Fax: 508/495-2393

Education Section: Excellence in Fisheries Education Award

The American Fisheries Society (AFS) Excellence in Fisheries Education Award was established in 1988. The award is administered by the Education Section and is presented to an individual to recognize excellence in organized teaching and advising in some aspect of fisheries education. Nominees may be involved in extension or continuing education, as well as traditional college and university instruction. Nominees must be AFS members, have been actively engaged in fisheries education within the last 5 years, and have had at least 10 years of professional employment experience in fisheries education. Two or more people may act as nominators, but at least one nominator must be an AFS member. The nominator(s) is responsible for compiling supporting material and submitting the application. The suggested format for applications can be found on the Education Section web site. Application materials should be sent in digital form.

Nomination deadline: 14 May 2010.
Contact: Jason Vokoun,
jason.vokoun@uconn.edu
Dept. of Natural Resources and the Environment
University of Connecticut
Phone: 860/486-0141

Education Section: John E. Skinner Memorial Fund Award

The John E. Skinner Memorial Fund was established in memory of John Skinner, former California-Nevada Chapter and Western Division president. The fund provides monetary travel awards for deserving graduate students or exceptional undergraduate students to attend the AFS Annual Meeting. The 2010 meeting will be held in Pittsburgh, Pennsylvania, September 12–16. Any student who is active in fisheries or related aquatic disciplines is eligible to apply. Awardees are chosen by a committee of the AFS Education Section. Selection is based on academic qualifications, professional service, and reasons for attending the meeting. Travel support (up to $800 per award) will be made available to successful applicants. Award winners will also receive a one-year paid membership to the American Fisheries Society. See the main awards page for Skinner Award Application-Part 1: Student AND Skinner Award Application-Part 2: Faculty. Electronic submission preferred.

Application deadline: 7 May 2010
Contact: Joseph E Hightower,
jhightower@ncsu.edu
U.S. Geological Survey
NC Cooperative Fish and Wildlife Unit
Campus Box 7617 NC State University
Raleigh, NC 27695
Phone: 919/515-8836
Fax: 919/515-4454

LETTERS: TO THE EDITOR

An article published in the January 2010 issue of *Fisheries* entitled "The Juvenile Salmon Acoustic Telemetry System: A New Tool" names Vemco's acoustic telemetry equipment and passes opinion on it. Unfortunately, some of the information is inaccurate and thus misleading.

The article states that Juvenile Salmon Acoustic Telemetry System (JSATS) is based on non-proprietary technology and that this has led to lower priced equipment. The $215 JSATS price mentioned here is for very large orders (numbers of 20,000 per year are mentioned in the article). Vemco pricing is comparable for orders of this size. To do an accurate price comparison, one must also consider the cost of the overall system including the price to purchase, deploy, and maintain associated receivers as well as the cost to acquire the data. Vemco VR2W receivers are relatively inexpensive at <$1,500 per node, the data is easily accessible, and they last more than one year on a single battery.

The article also suggests that the use of proprietary technology somehow limits advances. This is contrary to the common practice which has fueled technological advances for centuries, namely companies financing research and development, and thus new products, from profits. Vemco has been delivering leading-edge acoustic telemetry products to biologists around the world for over 30 years. Our customers tell us the top two reasons they choose our products year after year are reliability and affordability.

The Vemco technology is not restricted to the ocean. Any performance advantage we have in terms of range, or otherwise, will apply equally in freshwater. The VEMCO technology is used the world over in both fresh and marine environments, on large and small fish and with large groups of fast moving animals.

The article's take on tag coding is one-sided and could be considered misleading. It is true that transmissions are more frequent with the JSATS approach but to truly understand a system's performance one needs to know the received data rate and the amount of usable data captured rather than just the transmitted data rate. A highly aggressive coding system, such as that used by JSATS, will have a high rate of decode errors and false positive detections. This is not a criticism but a fact and these errors will increase over range and as acoustic conditions deteriorate. Vemco deliberately takes a conservative approach to our coding system and, as a result, decoding failures are extremely low. The penalty for this conservative approach is increased collision losses as the number of transmitters present at a receiver increases. Fortunately, collision losses are predictable and study parameters can be adjusted accordingly based on the size and nature of the study.

So while the transmission data rate of the JSATS approach is higher than that of Vemco, communication errors will diminish the received data rate considerably. The performance will be highly dependent upon the environmental conditions, which are difficult to predict, and can result in less usable data than with the more conservative Vemco approach. To truly understand the relative performance of the two systems, one would need to evaluate several factors, including the number of false positive detections and decode errors under various conditions. Without this analysis, to simply infer one system would be more effective or efficient than the other is unreasonable.

The article makes the claim that the Vemco tags used in the Columbia River are 7 times heavier (3.1 g in air) than the JSATS transmitter at 0.43 g. This seems like an unfair comparison as the Vemco tag referred to is by no means our smallest. The smallest V9 weighs 2.9 g in air, the V7 is 1.4 g, and the V6 is 1 g. This is public information on our website. As well, we have prototypes under evaluation with customers that weigh less than 0.65 g and 0.5 g.

The JSATS and HTI data shown are for freshwater whereas the Vemco data are for saltwater. This is important because the range in freshwater will, under good conditions, be much greater. In this specific case, the range for a V7 could be up to 600 m in freshwater where the table shows 292 m (saltwater estimate). That said, a more meaningful comparison would be to look at the typical spacing between receiver nodes used in the study.

Thank you for the opportunity to comment on this article. I do not wish to discount the good work being done by these researchers but rather correct any potential misunderstandings.

—Sandra Greer,
president and CEO,
Vemco (www.vemco.com)

THE AUTHORS RESPOND—

The information we included in our article on pricing and the comparisons between JSATS and Vemco products was added to the final version of the article in response to comments/requests from peer reviewers and the science editor. We did not intend to imply that the Vemco system is not also used to conduct good work the world over. For our article, we used the information on other acoustic telemetry systems that was available to us in the published literature and from vendor web sites.

Regarding tag costs and volume pricing, readers may contact the current JSATS tag vendor, Advanced Telemetry Systems (www.atstrack.com), to learn about quantity discounts. Regarding differences in system design and function, we stand by our assessment of relative strengths and weaknesses of the respective systems. The Vemco tags used in the published paper that we referenced weighed 3.1 grams in air. The JSATS tags used in our article weighed 0.43 grams in air. While Vemco may have smaller tags listed on their web site or in development, we are not aware of these smaller tags being used in studies of small fish in fast water, similar to the area where we used the JSATS.

We regret that we may have confused readers by including range estimates for both fresh and saltwater in our transmitter comparison table. The Vemco range in the table was calculated using the "range calculator" on their website (the site does not allow the user to select freshwater). Note, however, that in our discussion of detection probability (page 19) we assumed the V9 had a range of 600 m, which is consistent with Ms. Greer's letter.

Finally, an important distinction is that I and my coauthors are not telemetry equipment vendors; we are researchers who use telemetry products made by many vendors. The advertising nature of Ms. Greer's letter is understandable, because she is a vendor of acoustic telemetry equipment. As tag size changes, so does function, so researchers should beware when a vendor provides detection range and tag life data for one frequency or power output, and then tells you about their smallest tag (which they may report as weight in water, not weight in air). As researchers, we appreciate the need for and value of "apples-to-apples" comparisons.

—Geoffrey McMichael

OBITUARY: EDWIN L. COOPER

Past President of the American Fisheries Society

Edwin L. Cooper, 90, died in Houghton, Michigan, 3 November 2009. Cooper was born in Utica, Michigan, in 1919, the son of George Edwin Cooper and Ada Anna Dentel. He married Margaret E. Simmons in 1941 and he was honorably discharged from the U.S. Army in 1945, after serving in the medical administrative corps in Iceland during World War II. He received his bachelor's, master's, and doctoral degrees from the University of Michigan.

Cooper was the director of the Pigeon River Trout Research Area near Gaylord, Michigan, from 1948 to 1952, and the chief aquatic biologist at the Wisconsin Conservation Department in Madison from 1952 to 1956. He joined the faculty of the biology department at the Pennsylvania State University as an associate professor in1956, and he was promoted to professor in 1962. He retired in 1983.

A specialist in the study of fish, especially trout, Cooper and his colleagues produced the first computerized data bank on the fishes of Pennsylvania. They also assembled and preserved a collection of the fish of Pennsylvania. Active in numerous professional organizations, he served as president of the American Institute of Fisheries Research Biologists from 1968 to 1970 and as president of the American Fisheries Society in 1971–1972. He was also president of the AFS Northeastern Division in 1979–1980. He is the author of numerous publications in scholarly journals and the book *Fishes of Pennsylvania and the Northeastern States.*

He and his wife Margaret moved to Houghton in 2006. He is remembered by his family and friends for his sense of humor and generosity. Friends may make a donation to Omega House, in Houghton, Michigan.

VISITPITTSBURGH.COM

The AFS 2010 Planning Team has chosen a great host hotel, the Westin, for the 140th Annual Meeting. This facility (www.starwoodmeeting.com/Book/AFS2010, 412/281-3700) will provide excellent access to all meeting activities and amenities and is connected to the David L. Lawrence Convention Center by a skywalk. When making your reservations, and to secure the conference rate, be sure to mention that you are attending the AFS meeting. Visit the AFS 2010 Annual Meeting website www.fisheries.org/afs10 and click on the "Lodging/Transportation" link for complete information on how to make your reservations and travel directions.

Located in the center of the business and cultural district, the Westin provides guests with easy access to a variety of local attractions and entertainment options. From Monday through Friday, complimentary transportation is available from the hotel to the center of the business district, as well as the Heinz History Center (www.heinzhistorycenter.org), Andy Warhol Museum (www.warhol.org), PNC Park, Heinz Field, and Mellon Arena. The Westin also houses Pittsburgh's premier seafood restaurant, The Original Fish Market, and is just a few blocks from the popular nightlife and shopping area commonly called "the Strip District." The Westin is also just one mile from other popular visitor attractions: Carnegie Science Center (www.carnegiesciencecenter.org); Benedum Center for the Arts (www.benedumcenter.org); Heinz Hall for the Performing Arts (www.pittsburghsymphony.org), home to the Pittsburgh Symphony; and the Station Square complex (www.stationsquare.com).

Should it be needed, additional lodging has been secured at the Courtyard by Marriott and the Omni William Penn. Both hotels are located within easy walking distance of the David L. Lawrence Convention Center and offer convenient access to downtown Pittsburgh nightlife.

Once you're in Pittsburgh, you'll have plenty to see and do in addition to the scheduled meeting activities. Under the "Tours and Sightseeing" section of our website, check out the listings for "Things to Do in Pittsburgh" and "Pennsylvania Fishing Opportunities." Visit the Pennsylvania Fish and Boat Commission's interactive website at www.fishandboat.com, where you can select fishing opportunities by county (Pittsburgh is in Allegheny County) or select fishing "hot spots" by species, such as smallmouth bass or wild trout. Once on the website, please select "Fish" from the left navigation panel and then "Fishing Near You."

If you're interested in other outdoor activities that your family can enjoy, visit Venture Outdoors (www.ventureoutdoors.org), where you can find information about bike rides and renting kayaks. Paddling the rivers in downtown Pittsburgh is a great way to see another side of this beautiful city and its distinctive skyline. Or, take a relaxing ride on a paddlewheel boat to see the city skyline (www.gatewayclipper.com). For more information on Pittsburgh sites and events, see www.visitpittsburgh.com/essentials.

It's never too early to book your room and make travel arrangements for the busy, late-summer travel season, so make your plans now to attend the 2010 AFS Annual Meeting in Pittsburgh. Travel safely and we'll see you there!

DAVID L. LAWRENCE CONVENTION CENTER

PUBLICATIONS: BOOK REVIEW

Fish Reproductive Biology: Implications for Assessment and Management

EDITED BY TORE JAKOBSEN, MICHAEL J. FOGARTY, BERNARD A. MEGREY, AND ERLEND MOKSNESS. JOHN WILEY AND SONS, LTD., WEST SUSSEX, U.K. 2009. 440 PAGES. $209.99

In the introductory chapter of *Fish Reproductive Biology,* Tore Jakobsen and his co-editors note that direct measures of reproductive potential require counting eggs, but because traditional methods are time consuming, fecundity is rarely measured. The reader learns that proxies for reproductive potential, particularly spawning stock biomass, are commonly used instead. Such proxies may be convenient, but their widespread use may be diluting our understanding stock-recruitment relationships. This understanding is confounded when fish body size is not the only determinant of egg production, when selective harvesting has changed a population's demographics, or when large fluctuations exist in environmental productivity. Unfortunately, use of such proxies is common today, and this book shows how this can lead to an overly optimistic view of recruitment and stock status. Jakobsen et al.'s book not only outlines such problems but offers solutions to address them.

The book is organized into three sections. The first section reviews reproductive biology and population dynamics. This section's first chapter introduces the concepts and models relating stock and recruitment. The second chapter demonstrates the diversity of fish reproduction. The third chapter explores post-reproductive processes, particularly those occurring during the early life stages, which continue to modify the number and condition of recruits. The fourth chapter reviews the theoretical expectations and the evidence for fishing's impact on population abundance, phenotypes, and genotypes.

The second section of the book considers more applied issues of studying population dynamics. It begins with an overview of ichthyoplankton survey methods. Another chapter illustrates the value of identifying population structure in terms of appropriate management units. The third chapter walks the reader through a stock assessment process, step by step. The fourth chapter provides an overview of oogenesis and explains how fecundity may be measured efficiently, even rapidly.

The third section demonstrates how measures of reproductive potential and recruitment variability can improve stock assessments. This section's first chapter provides a brief history of stock assessment methods, and then highlights three common themes and includes cautionary notes on the shortcomings of each theme. A second chapter uses a case history approach, and assembles an interdisciplinary dataset to show how incorporating environmental factors can affect reference points. The last chapter focuses on the insensitivity of spawning stock biomass as a measure of reproductive potential while acknowledging the challenges ahead to changing the status quo.

Twenty scientists from eight countries contributed to this book. Despite this international perspective, the emphasis is on the marine rather than freshwater studies and focuses more on temperate-boreal ecosystems rather than on subtropical-tropical systems. The taxa emphasized are Northern Hemisphere herring and groundfish.

I especially appreciated that one chapter on stock assessment began with the position that "mathematics are a barrier to understanding for many people." The author lucidly explained this topic with words and pictures rather than equations. Nonetheless, this book does not avoid a quantitative approach, although the mathematical treatments used in other chapters are not beyond basic stock assessment techniques.

Throughout the book, a common theme is the effect of the environment on population dynamics, a very appropriate topic but one not apparent from the book's title. In fact, common sense shows that fish populations respond to environmental signals, such that egg production per fish is greater when ecosystem productivity is high and lower when productivity is below average.

In actuality, annual fecundity is measured in very few cases today, so it is still easy to challenge evidence that direct measures of egg production are a more sensitive and useful measure of reproductive potential than is spawning stock biomass. However, as evidence accumulates and reproductive biology is incorporated more fully into the assessment process, the accuracy and forecasting of at least "data-rich" stock assessments will surely improve.

This book presents a balanced review of quantitative and qualitative descriptions, field and laboratory experiments, and established and emerging mathematical models. I found few outright errors in the book, except several typos in the Literature Cited sections. The diversity of subject matter was matched by a diversity of writing styles, some easier to understand than others. The book includes 27 color plates, but color did not improve the interpretation of about half the images. When introduced, "maternal effect" was not defined even though this term is recognized as having multiple definitions (Green 2008), and it appears throughout the book. The index seemed incomplete; "spawning stock biomass" is listed only once and "skip spawning" is not listed at all. Such shortcomings are minor. Overall, the quality of this book is very good.

I read this book from cover to cover. It was tempting to sample just a few chapters, but the editors have organized the book so that reading it from beginning to end covers a wide spectrum of related disciplines. As one author put it: the goal

is to facilitate a "dialogue between assessment scientists and biologists." Readers of any specialty should accept this challenge, and this book is an excellent resource to aid them.

This book would certainly be an excellent choice for a reading course. It is not written at an introductory level, so students would benefit from previous graduate-level courses in fish biology and resource assessment. This is the kind of book that challenges the dogma of introductory courses as well as the methods professionals use to address familiar problems. Each chapter provides personal perspectives, highlights emerging case histories, and illuminates the background conversations that go on at professional conferences and assessment workshops.

In the preface of *Fish Reproductive Biology,* Jakobsen et al. set the following goal for this book: to make the reader aware of new methods that are leading to an improved understanding of fish reproduction and recruitment, and to show how such information is being applied in stock assessments. In doing this, this book will be a springboard for many fresh research ideas and it will foster further integration of fish reproductive biology and fish stock assessment.

—Richard S. McBride
Northeast Fisheries Science Center
National Marine Fisheries Service
Woods Hole, Massachusetts 02543, USA

REFERENCE

Green, B. S. 2008. Maternal effects in fish populations. Advances in Marine Biology 54: 1-105.

ANNOUNCEMENT: JOB CENTER

EMPLOYERS: To list a job opening on the AFS Online Job Center submit a position description, job title, agency/company, city, state, responsibilities, qualifications, salary, closing date, and contact information (maximum 150 words) to jobs@fisheries.org. Online job announcements will be billed at $350 for 150 word increments. Please send billing information. Listings are free (150 words or less) for organizations with Associate, Official, and Sustaining memberships, and for Individual members, who are faculty members, hiring graduate assistants. If space is available, jobs may also be printed in *Fisheries* magazine, free of additional charge.

M.S. Graduate Research Assistantship, University of Florida, Program in Fisheries and Aquatic Sciences (PFAS), Gainesville, and Tropical Aquaculture Laboratory, near Tampa.
Salary: $16,000 plus insurance and tuition.
Closing: 19 March or until filled.
Start date: Fall semester 2010.
Responsibilities: Investigate predator-prey dynamics in the context of community resistance to invasion and ecological risk analysis.
Qualifications: B.S. in ecology, fisheries, zoology, or related field. Well-motivated student who is excited about contributing to fish and invasion ecology. WorkS well within a diverse team. Strong quantitative and communication skills.
Contact: Send a cover letter, CV, unofficial transcripts, unofficial GRE scores, and contact information for 3 references to Jeffrey Hill, jeffhill@ufl.edu, 813/671-5230 x118. See the PFAS student information http://fishweb.ifas.ufl.edu/Student_Info.htm.

Fisheries Technician (temporary), Turner Enterprises, Inc., Bozeman, Montana (2 positions) and Vermejo Park Ranch, New Mexico (8 positions).
Salary: $9–11 per hour with overtime, depending on experience. Housing may be provided in some cases.
Closing: 20 March 2010.
Start and end dates: Flexible. June 1 to September 30 in Bozeman. July 26 to August 20 in Vermejo Park Ranch.
Responsibilities: Work with native species conservation and restoration. Help conduct stream electrofishing surveys, piscicide applications, aquatic population sampling, and other duties as assigned.
Qualifications: Related experience is helpful, but not necessary.
Contact: Carter Kruse, Turner Enterprises, 1123 Research Drive, Bozeman, Montana 59718; carter.kruse@retranches.com; 406/556-8508. Provide an electronic resume and letter of interest briefly describing their professional goals, school experience, and work experience. Please indicate position(s) of interest and window of availability.

Assistant/Associate Professor—Quantitative Fisheries and Ecosystem Modeling, School of Forest Resources and Conservation, Gainesville, Florida.
Salary: Commensurate with experience. 12-month tenure-track position.
Closing: Screening begins 15 March 2010, until filled.
Responsibilities: 40% teaching and 60% research. Build a strong research program in innovative modeling approaches that can inform management of recreational and commercial fisheries and aquatic ecosystems. Teach a graduate course in advanced fisheries stock assessment, one undergraduate course, and participate in one or more team-taught courses, some of which may contribute to the revised natural resources conservation major.
Qualifications: An earned doctorate in fisheries science or a closely related discipline is required. Postdoctoral experience is desirable. Demonstrated skill in advanced quantitative methods, e.g., likelihood and Bayesian parameter estimation, single and multi-species modeling, network analysis, verbal and written communication, interpersonal relationships, and procurement of extramural funding.
Contact: Micheal Allen, Search Committee Chair,msal@ufl.edu. See http://sfrc.ufl.edu/.

Student—Fisheries-induced Evolution (2 positions), University of Western Ontario, London, and Trent University, Peterborough.
Salary: $18,000 per year, teacher's assistantships and summer stipend.
Closing: 15 March 2010 or until filled.
Starting: May or September 2010.
Responsibilities: Study fisheries-induced evolution in Lake Huron lake whitefish as part of a modeling project funded by the Great Lakes Fishery Commission. Collaborate with two universities and the Ontario Ministry of Natural Resources. Work with Yolanda Morbey and Yingming Zhao at University of Western Ontario, and focus on models of size-selectivity of fishing gear and life history evolution. Or work with Erin Dunlop and Yingming Zhao at Trent University on a population dynamics and stock assessment model for lake whitefish.
Qualifications: Strong quantitative background, interest in applied fisheries research in the Great Lakes, proficient in data management e.g., MS Access , data analysis e.g.,

SAS or R, and computer modeling e.g., AD Model Builder, MatLab, or C, and knowledge of evolutionary theory.
Contact: Send a c.v., unofficial transcripts, and a letter outlining your qualifications and interests to Yolanda Morbey, ymorbey@uwo.ca.

Fisheries Technician (student), University of Florida. Reside in Flagstaff, Arizona, and perform field work in Grand Canyon, Arizona.
Salary: $1,000 per month. Field housing, meals, and gear provided.
Closing: 15 March 2010.
Responsibilities: Conduct research assessing the impact of experimental flows on the Grand Canyon fish community. Participate in electrofishing, hoopnetting, seining and sonic telemetry survey. Learn basic fisheries techniques including fish identification, tagging methods, fish handling techniques, and basic experimental design approaches. Participate in four 20 day river trips during July through October. Assist graduate students with daily tasks including gear preparation and data entry.
Qualifications: Preference given to students studying fisheries ecology.
Contact: Send resume and three references to nearshoreecology@gmail.com. See www.floridarivers.ifas.ufl.edu

M.S. or Ph.D. Assistantship in Fisheries/Aquatic Ecology, University of Illinois, Natural History Survey.
Salary: $17,000 per year, including tuition waiver.
Closing: 15 March 2010.
Starting dates: In June through August 2010.
Responsibilities: Research topics are varied and flexible, but individuals with interests related to four projects are preferred—(1) recruitment, behavior, physiology, reproductive strategies, and management of largemouth bass; (2) population ecology of muskellunge;(3) application of physiological approaches to stream restoration with Cory Suski , and (4) population and community ecology of Lake Michigan fishes with Sergiusz Czesny.
Qualifications: B.S. or M.S. in fisheries/aquatic ecology
Contact: Send a cover letter, resume, copies of transcripts, GRE scores, and three letters of reference to David H. Wahl, University of Illinois, 1816 S. Oak Street, Champaign, Illinois 61820; d-wahl@illinois.edu; 217/728-4400. See www.inhs.uiuc.edu/fieldstations/kbs/KBS_research.html.

Fisheries Scientist, Normandeau Associates, Inc.; New Hampshire.
Salary: Depends on experience.
Closing: 1 April 2010.
Responsibilities: Design and conduct successful field fisheries programs. Communicate and write reports. Support senior staff in population monitoring and impact assessments. Implement programs. Monitor quality control, data analysis and interpretation. Travel to and participate in field fisheries programs. Occasional overtime, weekend, or evening work may be required to meet deadlines.
Qualifications: M.S. in biology, zoology, fisheries, or related discipline with 1–3 years of experience and a broad background in freshwater or marine fish population ecology, with emphasis on quantitative field applications. Experience in sampling design statistics, population models, mark-recapture techniques, and SAS programming. Must be able to work in U.S. without company sponsorship.
Contact: Submit cover letter and resume to Robyn Chadwick, rchadwick@normandeau.com.

Internship, Illinois Natural History Survey, Ridge Lake Biological Station, Charleston, Kaskaskia, Sullivan, and Sam Parr Biological Station, Kinmundy, Illinois.
Salary: $1000 per month for 3 months, on-site housing provided if needed. Internship can also be used to earn university credits.
Closing: 1 May 2010.
Responsibilities: Work summer or year round. Work in the areas of aquatic ecology, fisheries management, and aquaculture. Assist with field sampling, laboratory experiments, and data processing and analysis. Internships can be tailored to individual interests.
Qualifications: Candidates should be working toward B.S. degree in fisheries, natural resources, biology, zoology, or related fields. Individuals interested in continuing on towards M.S. degrees or state or federal employment are encouraged to apply.
Contact: Matt Diana, Ridge Lake and Kaskaskia Biological Stations; mattd@illinois.edu; 217 728-4851. Or Michael Nannini, Sam Parr Biological Station, mnannini@illinois.edu, 618 245-6348,

Postdoctoral Associate—Marine Animal Diseases, The School of Marine and Atmospheric Sciences, Stony Brook University, New York.
Salary: Depends on experience.
Closing: 1 August 2010.
Responsibilities, qualifications, and contact: See www.stonybrook.edu/job, Category K, JOBS Reference WC-S-6230-10-01-S.

Ph.D. Research Assistantship, Pennsylvania Cooperative Fish and Wildlife Research Unit, Pennsylvania State University, State College.
Salary: To be determined.
Closing: Until filled.
Responsibilities: Integrate data from downscaled atmosphere-ocean general circulation models and land use change projections to identify how climate and land use change will impact fish habitat in the northeast U.S. and to determine the biological response of brook trout to projected habitat changes.
Qualifications: Minimum M.S. degree in fisheries, ecology, or a related field; a GPA of 3.0 or greater; and competitive GRE scores. Knowledge of ArcGIS and programming in R is desirable.
Contact: E-mail a cover letter describing research experience and interests, CV, transcripts, GRE scores, and contact information of three references to Tyler Wagner, txw19@psu.edu, and Paola Ferreri, cpf3@psu.edu. For information about individual positions, contact primary investigators. For information about the project in total, contact Doug Beard, dbeard@usgs.gov; Craig Paukert, cpaukert@ksu.edu; or Jeff Kershner, jkershner@usgs.gov

Postdoctoral Fellow, University of Minnesota—Duluth.
Salary: To be determined.
Closing: Until filled.
Responsibilities: Participate in an effort to predict specific changes in thermal habitat in coldwater lakes, along with corresponding changes in water quality and fish assemblages resulting from altered climate and land use. Develop and apply analytical approaches including both empirical and mechanistic models. Possibly model ways in which changes in climate and land use may affect changes in habitat in coldwater lakes, quantifying responses of fish assemblages and water quality to changes in environmental conditions, and work with other members of the project team to develop an approach for rating the potential vulnerability of the glacial lakes of Michigan, Minnesota, and Wisconsin to climate and land use changes. Interact with other researchers who are developing individual-lake models that predict temperature and oxygen in coldwater lakes.
Qualifications: Ph.D. in aquatic or fisheries ecology, or related field a strong quantitative background experience with geographic information systems, preferably ARCGIS, and excellent written and verbal English.
Contact: Position supervisor, Lucinda Johnson, ljohnson@d.umn.edu.

Postdoctoral Research Associates (2 positions) and Doctoral Research Student Assistant (1 position), Michigan State University.
Salary: To be determined.
Closing: Until filled.
Responsibilities: Post docs will classify river reaches into thermal and hydrologic types. Model ways in which changes in climate and land use may affect changes in habitat of fluvial systems. Quantify responses of fish assemblages to changes in environmental conditions. Develop an approach for rating the potential vulnerability of the nation's fluvial systems to climate and land use changes. Lead the effort to quantify the vulnerability of streams to changes in climate

and land use and to predict changes in distributions of fishes that may result at a national scale. Focus on the Midwestern Glacial Lakes Partnership region and will lead the effort to predict specific changes in thermal and hydrologic regimes along with corresponding changes in fish assemblages from altered climate and land use. Develop and apply analytical approaches for making research determinations.

Doctoral student will develop a project to evaluate the response of fluvial fishes to physical and biological changes in stream systems that may result from changes in climate and land use, with special emphasis on considering mechanisms by which landscape-scale controls affect fishes. Potential focus areas include considering altered physical habitat characteristics and/or response of assemblages to changes in species membership. Assist with data management, analysis, literature reviews, and other duties.

Qualifications: Ph.D. in aquatic or fisheries ecology, landscape ecology, or related field; a strong quantitative background; and experience with geographic information systems, preferably ARCGIS.

M.S. in aquatic or fisheries ecology, landscape ecology, or related field is required. Experience with geographic information systems, preferably ARCGIS, strong quantitative interests, and excellent written and verbal communication skills.

Contact: Dana Infante, Michigan State University, and Lizhu Wang, Michigan Department of Natural Resources. See www.msu.edu/~infanted.

Using Acoustic Tags to Monitor Movement and Habitat Use of Chinook Salmon Smolts, Northern Pikeminnow & Smallmouth Bass

Located east of Seattle, Lake Washington supports the world's longest floating bridge at 7,578 ft (2,310 m), commonly referred to as the “520 Bridge” (State Route 520). The 520 Bridge connects Seattle with Eastside communities and is a high priority with the Washington State Dept. of Transportation (WSDOT) as they move forward with replacing the aging bridge.

When WSDOT began the SR 520 Program, they set out to better understand fish behavior with the help of the U.S. Fish and Wildlife Service (USFWS). It's known that structures, such as bridges in and near waterways, can influence the ecological dynamics of the aquatic environment. Such influences can affect behavior, habitat use, and survival. For example, many naturally-reared Chinook salmon smolts (*Oncoryhnchus tshawytscha*) in Lake Washington must pass beneath the 520 Bridge as they migrate toward Puget Sound. The goal of the study was to evaluate movement and habitat use of the salmon smolts and two predators - northern pikeminnow (*Ptychocheilus oregonensis*) and smallmouth bass (*Micropterus dolomieu*) near the bridge..

Researchers employed HTI's fine-scale acoustic tracking system to track fish in a 17.2 ha area along a 1,838 ft (560 m) stretch of the bridge from late May through early August. The study site was on the west end of the bridge, and was believed to lie within a major migratory corridor for salmon smolts. Naturally-reared smolts moving from south Lake Washington travel north along the western shore of the lake and encounter the bridge before moving toward the entrance to the Lake Washington Ship Canal en route to Puget Sound. Hatchery-reared smolts occur throughout the lake and many move along the southwestern shore of the lake and encounter the bridge. Tagged smolts were released 2,625 ft (800 m) south (upstream) of the study site to observe behaviors as they volitionally entered the study site and encountered the bridge. Most predators were captured on-site, tagged, and released near the place of capture.

Though differences in timing of migrational cues (e.g., moon apogee), physiological smolt status, water temperature, and prey availability may have contributed to differences in behaviors observed between release groups, the ultimate questions remain. How does the current bridge affect fitness and survival of Chinook salmon, and how should the new bridge be designed and sited to minimize impacts to Chinook salmon?

HTI is proud to provide the tools needed for WSDOT and USFWS to observe fish behavior, and for the opportunity to be involved as they continue their commitment to environmental stewardship. To learn more about acoustic technology used in this study, visit us at HTIsonar.com.

Day and night density plots of northern pikeminnow #4667 at State Route 520 Bridge study site, summer 2007.

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