The Biomechanics of Fly Casting by Al Kyte, Ed.Dr., Univ. of California and Gary Moran Ph.D. University of San Francisco

PLEASE BEAR WITH US WHILE WE LEARN HOW TO BRING UP THE DRAWINGS. THEY ARE IMPORTANT.

Why do some fly casters cast so far, and with so little effort? As fly-casting instructors we wanted to answer those questions. You see, teachers like to have answers, and fly-casting teachers are no exception. Unfortunately the "answers" we have, even the techniques that have worked before, are sometimes too narrow and dogmatic to help the next student. Professional teachers and athletic coaches try to improve there teaching by using anatomical and mechanical principles, called sport biomechanics, as the basis for what they teach.

Researchers in biomechanics have filmed or videotaped groups of skilled performers in variety of sports, but we found little research on fly casting, so we decided to conduct our own study and combine the perspective of a fly-casting teacher with that of a biomechanics researcher. Here's what we discovered.

Design of the study

Analyzing the videotaped performances of a group of casters, rather than a single caster, helped us identify acceptable variations in casting form as well as to verify which mechanical components are most important. For such comparisons to mean anything, each caster had to perform the identical casting task with the same rod and fly line.

We decided to concentrate on casting for distance to analyze the mechanics of maximal force application. We wanted to identify what some of the most successful distance casters in this sport do differently from other skilled casters. Our sample group of 20 casters included tournament fly casters as well as highly regarded trout and steelhead anglers from northern California.

We conducted the casting indoors to eliminate any disruption from wind or other elements and kept the casts within the space limitations by specific selection of the fly rod and line and by standardizing the length of line being false-cast prior to the final forward cast.

We sought a "progressive, medium-action" fly rod and full-length fly line, representative of those commonly used by anglers. We also needed a white fly rod for maximum contrast against a black background. Mel Kriger donated one he had used in his excellent video, "The essence of Fly Casting." This

9-foot graphite fly rod designed for Fenwick by Jim Green, was matched with a Scientific Angler/3M Ultra22, weight-forward 7-weight floating fly line.

Preliminary testing and videotaping revealed the need for markers on the casters' joints (wrist, elbow, shoulder, hip, knee and ankle), a black backdrop curtain, horizontal and vertical reference lines to facilitate angler measurement, and a system for identifying subject and trial numbers within the filming area. We also developed a procedure for evaluating casting loop size and other fly-line characteristics that occurred beyond the filming area.

Though lacking sophisticated, high-speed biomechanics equipment, we recorded the casts using two video camcorders and analyzed the data using a multifunction stop action, frame-by-frame and slow motion playback-capable VHS videocassette recorder.

We gave each caster a 15-minute practice period with the task and equipment. After this practice period, each person made 14 casts, attempting to cast the fly as far as possible. We recorded the distance the fly landed form the caster for each trial. We gave a distance score to each caster, the average of that person's successful casts.

Nine of the 20 casters who cast the fly the greatest distance became the "elite" group. This group included world-class tournament casters Rene Gillibert and Tim Rajeff as well as renowned teachers/angler Mel Kriger and Andre Puyans. The nine casters, whose scores fell midway between these two groups, where removed from the analysis to ensure that the two comparison groups were distinctly different.

F i n d i n g s

The elite group cast the fly an average distance of 80 feet compared to 70.7 feet for the good group. The skills of these casters and the limitations placed on distance by the task and equipment notwithstanding, then feed of distance in this study represents a substantial difference.

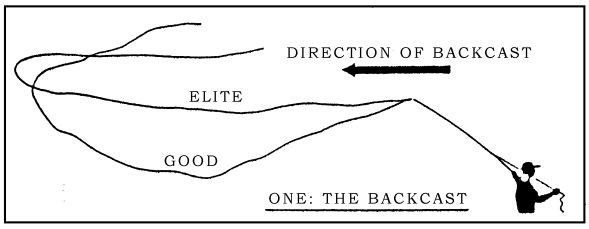
In the following discussions we have grouped the findings into three sequential stages of the cast – the backcast, the loading of the forward cast, and the unloading or stop of the forward cast.

The casters in the study had to pick up and control approximately 50 feet of fly

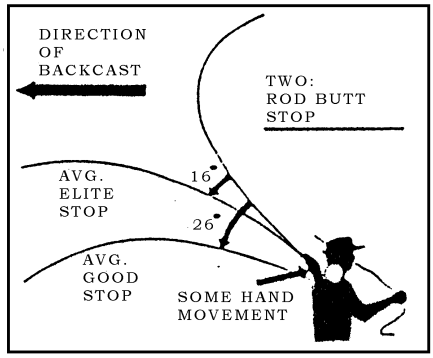
line in the air, make two false casts, and releases line on the third forward cast. Every caster used line-hauling techniques.

Although the backcast occurs prior to any power application of the forward cast, and may no contribute directly to distance, it does serve to straighten the line behind the rod tip. Any slack that remains in the line when the forward cast begins can interfere with the distance of that cast

Movement of the fly line. The elite casters straightened the backcast line more completely than the good casters and did so with noticeably smaller loops (Figure 1). The variable that most affected this line flow was the way the casters stopped the rod at the end of the backcast. This is when the rod loses its bend and transfers energy to the line.



The backcast stop. The elite group stopped the rod more abruptly, moving the butt an average of 16 degrees as compared to 26 degrees for the good group. This "stop" is measured from the point of the rod's maximum bending the backcast to the point at which the rod first deflected downward (Figure



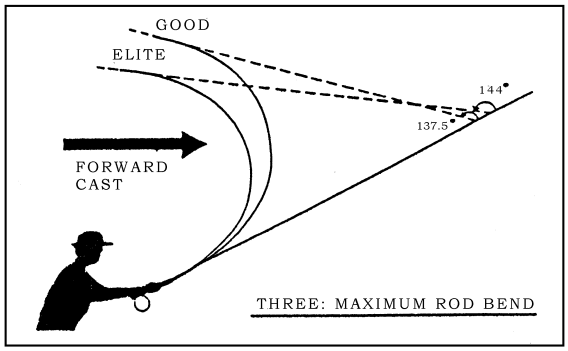
2).

Some of the "good" casters also moved the casting hand and rod butt lower during the stop. This extra movement combined with the greater angle change of the rod butt allowed the rod tip to drop lower in back than was typical of the elite group. Dropping the rod tip low during the backcast put sag in the backcast line and decreased the likelihood of achieving small, efficient loops.

Although we are familiar with this tendency among beginning casters, we found that it reappears in some experienced casters when they attempt long backcasts.

When you apply force to drive the line forward, energy is being stored in the increasing bend of the fly rod. This is commonly referred to as "loading" the rod. We found a number of variables that contribute to force application in this loading phase.

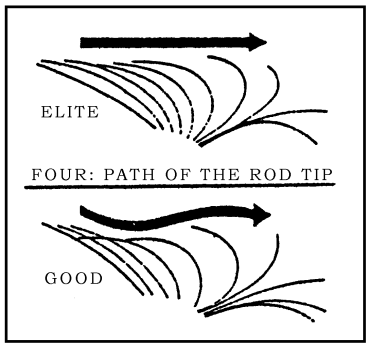
Maximum rod bend. We expected our more



successful distance casters to store more energy by forcing more bend into the rod. To examine this factor, we measured the extent to which each caster bent the rod tip back from the rod butt. Where we found the rod tip bent back from the butt the greatest amount, we applied the term "maximum rod bend."

We found that the caster who cast the fly the farthest also bent the tip back the farthest, 152 degrees. The caster with the second best distance had the second greatest rod bend, of 149 degrees. The elite group averaged 144 degrees of maximum rod bend compared to 135.7 degrees for the good group (Figure 3).

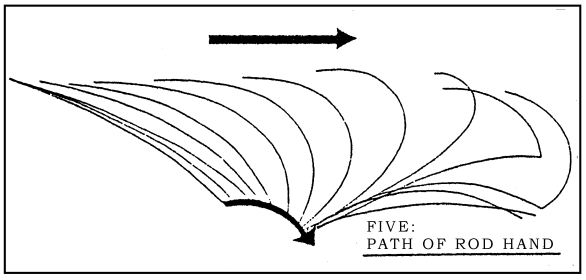
Only one caster in the good group bent the rod back more than 140 degrees, but be had an obvious backcast problem that accounted for his lower distance score. We believe this to be among the most important variables in casting for distance, although it hasn't been emphasized thus far in the casting literature.



Path of the rod tip. Casting instructors commonly teach that the rod tip should move along a straight path throughout the loading phase. This phenomenon is similar to "flattening the arc of the swing" in other stroking movements, such as the tennis forehand.

In this study all nine elite casters did move the rod tip in straight path, achieving maximum rod bend just before the stop. Yet only two of nine good casters

achieved the timing necessary to maintain this straight path. The common error among these casters was to apply their maximum force too early in the stroke (figure 4).

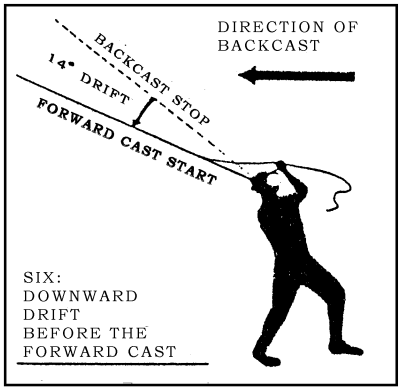


Casting instructors sometimes teach that the casting hand should also move in a straight line during this loading phase. Yet from the side view we found that rather than in a straight line, the hand typically moved forward in a slightly downward curving path (figure 5). There was some variation in this path, depending on the throwing style of the caster. Regardless of this variation, the casting hand, elbow, and shoulder of each elite caster interacted to produce the important straight path of the rod tip.

Angle of release. The "angle of release" is the number of degrees above horizontal that the fly line starts moving forward from the rod. This variable is critical in throwing events that many people consider similar to distance casting.

We found release anglers anywhere from horizontal to 20 degrees above horizontal, but both the elite and good groups averaged a surprisingly low release angle of 6 degrees above horizontal. Several casters volunteered the information that the indoor conditions caused them to use lower release angles than normal to achieve their longest casts.

Cast arc. The most important findings thus far where that the elite casters impaired more bend into the rod and did so with better timing. Yet, what did they do differently to achieve this additional bend? This question led us to examine other mechanics of the rod, such as the casting arc and stroke length.



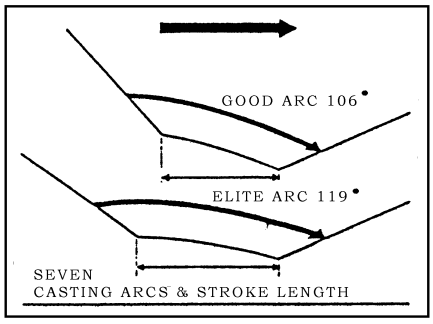
The "casting arc" refers to the angle through which the rod butt rotates during the casting stroke. Teachers often express it in terms of positions on a clock face, such as an arc from 10 o’clock to 2 o’clock. For this study we started the forward casting arc where the rod first showed a slight but measurable amount of bend and ended it where the rod first

completely straightened during the unloading phase.

Mel Kriger introduced the concept of a "variable casting arc" to indicate the need to vary the size of the arc's angle according to the amount of bend in the rod – the more bend, the wider the arc. The amount of bend depends on the stiffness of the fly rod, the amount of force being applied to the rod. The first two of these factors were made uniform in this study, requiring casters to use additional force to achieve the additional bend for a long cast. Thus we expected the elite group's additional rod bend to be accompanied by wider casting arcs than used by the good group.

We found that the elite casters did indeed move the rod through a wider range of motions than the good casters, averaging an arc of 119 degrees (4 clock positions) as against 106 degrees (3½ clock positions) for the good casters. Several of the best distance casters opened the casting arc even farther, to between 125 and 132 degrees. They accomplished this by letting the rod ""drift"" down in back and additional 10 to 15 degrees after the stop of the backcast (Figure 6).

This is similar to baseball batters who are moving the bat back even as they start shifting weight forward into the stride toward the pitcher. Some casting teachers emphasize an upward movement of the rod after the backcast but miss out on the additional range of motion available to a rod that is allowed to "drift" down a few degrees in back.



Stroke length. The stroke length is the distance the caster's hand moves the rod butt toward the target as the rod moves through its arc. This was measured by using a horizontal reference marker in the film view.

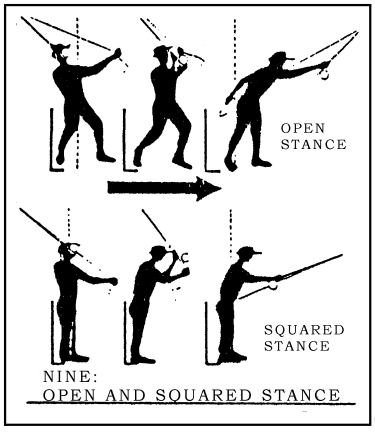
Stroke length among these casters varied from less than three feet (31 inches) to almost six feet (68 inches). The elite casters moved the rod butt forward an average of 57.3 inches during the cast as compared to 51.5 inches by the good casters (Figure 7).

The somewhat slow action (lack of stiffness) of the study fly rod invited a longer stroke than would have occurred with a stiff, fast rod. Nevertheless, the more successful distance caster used longer casting strokes and wider casting arcs than did the other casters, and did so over the same amount of time. This extra distance enabled the elite casters to apply additional force to the rod without loosing the straight path of the rod tip.

Stroke length, as such, may not be as important to casting distance as what the caster does to achieve that stroke length. We wondered if our best distance

casters applied force differently than the others to driver the rod butt forward. This question led us to shift our attention from the mechanics of the rod and line to the mechanics of the caster. Although teachers advocate carious styles of casting with different stances and arm movements, there is a lack of systematic investigation on the body's role in applying force to a long cast.

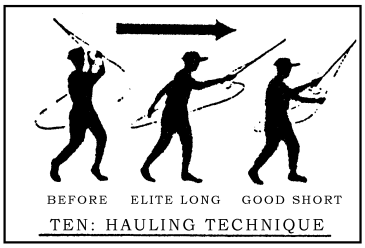
Force from the body. In other distance throwing sports, the athlete generally starts with the throwing side of the body turned away from the target and then brings that side forward vigorously when applying force. The whole body becomes involved in the force application. In this study, 16 of the 20 casters used such a "distance stance" by placing the casting side back. This open or dropped-back stance allows greater weight shift and body lean, more shoulder rotation, and a longer stroke than either the squared or closed stance.



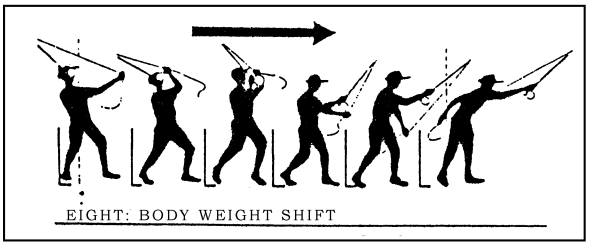
NINE:
OPEN AND SQUARED STANCE

Our elite casters made greater use of their body mass and musculature to load the rod than did our good casters. Six of nine elite casters used a pronounced weight shift from the back foot to the front foot during the forward cast. Only one of the nine good casters used such movement. In addition, the elite group averaged 40 degrees of back-to-front body lean as compared to 30 degrees for the good group. Eight of the nine elite casters rotated the casting shoulder forward in applying force as compared to only four of nine good casters. In combination, these factors can contribute an impressive amount of bend to the rod (Figure 8).

Two of our elite casters used a squared stance, with the feet positioned side by side. Although this style offers little potential for trunk rotation and lower-body weight shift, these casters leaned their upper bodies back and then bent forward explosively on the forward cast. The possessed the upper-body and arm strength as well as the precise timing to make this style effective. As teachers, we sometimes need to remind ourselves that one set of mechanics doesn't always work best for everyone (Figure 9).

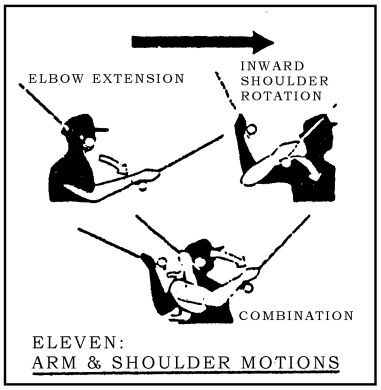


TEN: HAULING TECHNIQUE


EIGHT: BODY WEIGHT SHIFT

Hauling with the line and. The noncasting hand and arm also contribute to rod bend when casters "haul" or pull on the line during the loading of the forward cast. This is the second of two hauls in the double-haul technique used by most distance casters. In this study eight of the nine elite casters had highly effective hauls during the forward cast as compared to only three of nine good casters.

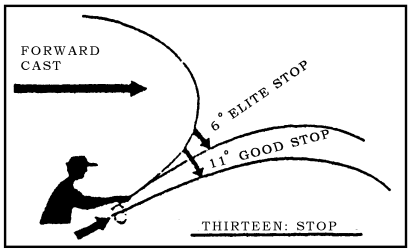
The most effective haulers pulled the line back for greater distance than the other casters primarily during the final, accelerated stages of loading. Thus they stopped the haul and released the line father back as well (figure 10). Short hauls, which are better suited to the action of stiff, quick-recovering rods, were less effective here. Some times instructors neglect to teach students to vary the length of the haul to coincide with the timing demands of the fly rod being used.



ELEVEN:
ARM & SHOULDER MOTIONS

The casting arm. For years fly-fishing authors have compared the arm motion of a distance fly cast to theory of a ball throw, even though a long implement has been placed in the hand. In ball throws we typically use the muscles of the throwing arm and hand top accelerate and finish off the force application that started in the large and more massive muscles of the legs and trunk.

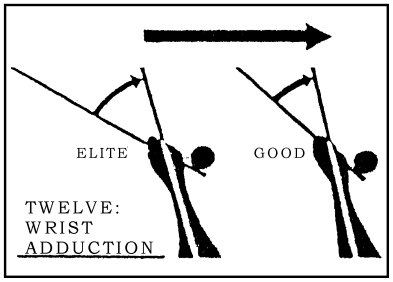
One component of a throw that many casting instructors emphasize is the positioning of the elbow forward of the shoulder and hand. This positioning offers the potential for strong elbow extension. Most of the casters in this study did position the elbow forward in this manner. Both the elite and good casters averaged 67 degrees of elbow extension during the loading of the forward cast.



We observed several variations in "throwing style" but the most common was one in which the elbow was brought out to the side of the body and remained there throughout the forward casting stroke. Sometimes teachers are critical of this arm style because of weaker elbow action. Yet this style uses a different component of throwing mechanics, a forceful inward rotation of the arm at the shoulder joint. This style frequently evolves in anglers who habitually wade deep or fish from float tubes and need to keep the elbow up out of the water.

Some of the most impressive casters in this study those who seemed to achieve the greatest line speed combined the components of both of these styles. The moved the elbow out to the side of the body during the backcasst, which opened the way for inward rotation at the shoulder. Then they moved the elbow ahead of the shoulder during the forward cast, which enabled them to use a strong elbow extension (Figure 11).

The casting wrist. Many beginning casters are trained to keep the wrist firm when learning to load a fly rod, and we observe that a wrist-dominated stroke limits the casting potential of many successful anglers. Yet the experienced distance casters in this study did use an "educated" wrist action during the final acceleration of the rod tip.



The anatomical term for the wrist action we used in the forward cast is adduction. This occurs when the little finger side of the hand moves close to the forearm as the thumb side moves farther away from

it. The elite group averaged 45 degrees of wrist adduction during the forward cast as compared to 35 degrees for the good group (Figure 12).

Some of this difference occurred as the elite casters opened up the wrist angle to let the rod drift downward in the back after the stop of the backcast. This movement not only widened the available casting arc but also placed the wrist in a position to contribute more movement and force to the cast.

Most of the casters in both groups saved the last 20 to 30 degrees of wrist action to quickly tilt the rod butt forward just before the stop of the cast. This wrist movement added to the bend of the rod tip as well as to its acceleration, and thus constituted the final component of the loading phase.

Mel Kriger cautioned us not to overlook the way a rod unloads at the end of the cast. Some teachers emphasize this moment with phrases such as "accelerate to a stop" or "come to a forced stop."

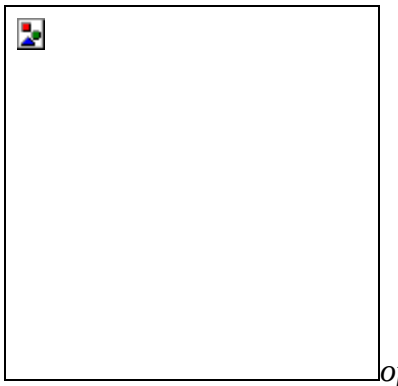
An abrupt stop of the hand and rod butt should direct the release of the stored energy out through the rod tip to the fly line. Theoretically any hand movement or change in the rod-butt angle during this stop phase represents a softening that allows some energy to escape down through the hand. This would result in less efficient use of the energy stored in the bent rod.

The most successful distance casters stopped the rod so abruptly that the butt moved barely one degree. This is very impressive when one considers that the rod tip was turning over so forcefully that some of the good group were unable to even hold the rod steady. As a group, the elite casters restricted rod-butt angle changed to less than six degrees during the stop. It took the good group more than 11 degrees, or roughly twice the butt angle change, to stop the rod (Figure 13).

Summary and Cautions

Sometimes we teach casting based on what we think is happening to the rod, line, or caster. The value of analyzing a group of skilled casters in a study such as this is that we can see what actually happens. This is particularly important when one is casting for distance, because the mechanics of a 75-foot cast require more force and complexity than those of a 25-foot cast.

"The value



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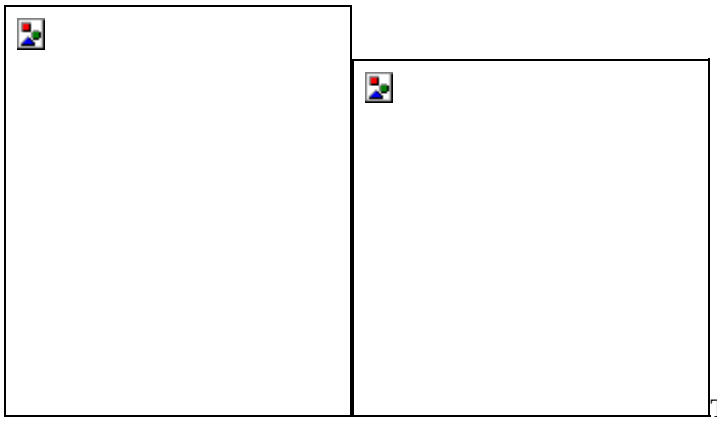

The elite casters in this study were able to store more energy in the bent rod than the good casters and were able to release that energy more efficiently to the fly line. The top distance caster bent the rod the most, stopped it the quickest, used the most body lean, had among the best-rated backcasts, had among the widest casting arcs, hauled line effectively, kept the rod tip straight during acceleration, used weight shift and shoulder rotation to his advantage, and benefited from a late forceful use of elbow and wrist action. Of the many dimensions analyzed, he had no discernible flaw. By contrast, we could see several ways in which each of the skilled casters in our good group could benefit from improved mechanics.

The precise anglers and lengths reported here should not be applied in a

general manner, because they are dependent on the specific fly rod and line used and the casting task of this study. The differences observed are the important findings of the study. We hope that these findings will serve as a basis for more sophisticated biomechanics equipment.

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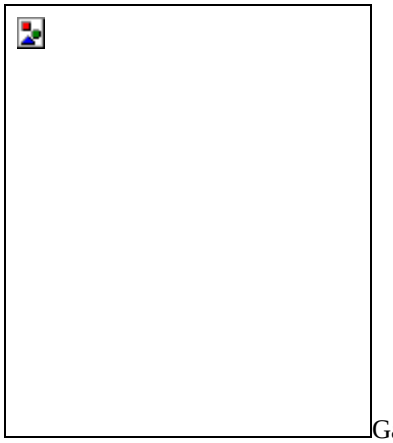

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Illustrated by Rod Walinchus.

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